TRANSACTION

AND

PROCEEDINGS

OF THE

ROYAL SOCIETY OF NEW ZEALAND

VOL. 64
(Quarterly Issue)

EDITED AND PUBLISHED UNDER THE AUTHORITY OF THE COUNCIL
OF THE ROYAL SOCIETY OF NEW ZEALAND

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NEW ZEALAND INSTITUTE.

NOTICE TO MEMBERS.

THE publications of the New Zealand Institute consist of

1. Transactions, a yearly volume of scientific papers read before the local Institutes. This volume is of royal-octavo size.

2. Proceedings, containing report of the annual meeting of the Board of Governors of the New Zealand Institute, list of members, etc. The *Proceedings* are incorporated with the quarterly numbers of *Transactions* supplied to members.

3. Bulletins. Under this title papers are issued from time to time which for some reason it is not possible to include in the yearly volume of *Transactions*. The bulletins are of the same size and style as the *Transactions*, but appear at irregular intervals, and each bulletin is complete in itself and separately paged. The bulletins are not issued free to members, but may be obtained by them at a reduction on the published price.

LIBRARY PRIVILEGES OF MEMBERS.—Upon application by any member to the Librarian of the New Zealand Institute or of any of the affiliated Societies such works as he desires to consult which are in those libraries will be forwarded to him, subject to the rules under which they are issued by the Institute or the Societies. The borrower will be required to pay for the carriage of the books. For a list of the serial publications received by the Library of the New Zealand Institute, see vol. 60, pp. 638-650.

ADDRESSES OF MEMBERS.—Members are requested to notify the Secretary of any change of address, so that the same may be noted in the List of Members.

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TRANSACTIONS

AND

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OF THE

ROYAL SOCIETY OF NEW ZEALAND

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By the Royal Society of New Zealand Act, 1933,* the New Zealand Institute constituted by the New Zealand Institute Act, 1908, was abolished, and, with His Majesty's gracious approval, a body was constituted as successor to the New Zealand Institute to be called the Royal Society of New Zealand. The new Act is dated 6th December, 1933; from that date the name of the New Zealand Institute disappeared and the new title was adopted.

The Royal Society of New Zealand is now in possession of all the properties and has assumed all the responsibilities of the New Zealand Institute. All members and officers of the New Zealand Institute at 6th December, 1933, continue as members and officers of the Royal Society of New Zealand. Regulations, rules, resolutions, and orders became as effective under the Royal Society of New Zealand as they were under the New Zealand Institute, and all matters and proceedings begun under the New Zealand Institute may be continued, completed, and enforced by the Royal Society of New Zealand.

The Royal Society of New Zealand Act is a machinery measure for effecting a change of title. Under the New Zealand Institute Act, 1908, the Board of Governors was the corporate body; the Royal Society Act makes the Society the corporate body. The Act effects improvements in the method of conducting the affairs of the Society. The Governor-General becomes Patron instead of being a full member of the Board now called a Council. In the long title of the Act the words "a body for the promotion of science" revives an expression of purpose which was present in the Act of 1867 originally constituting the New Zealand Institute Act, but was omitted from later Acts dealing with the New Zealand Institute.

In other minor matters the Act gives that authority for doing what the New Zealand Institute has been in the habit of doing without authority. The Act specifies in detail the Society's power of making rules. Clause 11 repeats Section 7 of the Finance Act, 1925, stating the amount of the annual endowment from Parliament to be £500.

* Which will be printed later in the Volume.

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OF THE

NEW ZEALAND INSTITUTE

1933

ANNUAL MEETING OF THE BOARD OF GOVERNORS, 18th MAY, 1933.

MINUTES.

The annual meeting of the Board of Governors of the New Zealand Institute was held on Thursday, 18th May, 1933, in the Biology Lecture Hall, Victoria University College, Wellington.

Roll Call: The Vice-President called the roll of members of the Board for 1933, and there were present the following:—Messrs B. C. Aston, M. A. Eliott, W. R. B. Oliver, Dr E. Marsden (representing the Government), Professor H. W. Segar, President, and Mr A. T. Pycroft (representing Auckland Institute), Professor H. B. Kirk and Dr E. Kidson (representing Wellington Philosophical Society), Dr C. Coleridge Farr and Professor R. Speight (representing Philosophical Institute of Canterbury), Professor T. H. Easterfield (representing Nelson Institute), Professor J. Park (representing Otago Institute), Mr G. V. Hudson (representing Hawke's Bay Philosophical Institute), Dr P. Marshall (member co-opted under Section 3 (b) Amendment Act, 1930.

His Excellency the Governor-General and the Rt. Hon. the Prime Minister were both absent from Wellington.

Presidential Address: Professor Segar read his presidential address, and in doing so referred to the loss sustained by the Institute in the death of several members and honorary members. He mentioned that three honorary members had passed away, namely, Professor J. W. Gregory, D.Sc., F.R.S., F.G.S., late of the University of Glasgow; Sir Ronald Ross, discoverer of the malarial parasite; and Sir Arthur Thomson, M.A., LL.D., Regius Professor of Natural History at the University of Aberdeen. At the conclusion of the address Professor Easterfield moved a hearty vote of thanks to the President for his address, and asked that he allow it to be printed in the Transactions. Carried unanimously.

Motions of Sympathy: Resolutions of sympathy with Mr G. M. Thomson, who had recently undergone a severe operation, and with Sir Thomas Sidey, who also was seriously ill, were carried on the motion of Dr Farr.

Notices of Motion were then called for and received.

Fellowship N.Z. Institute: The President then read the report of the Fellowship Selection Committee, which was as follows:—"As the number of Fellows may not at any time exceed 40 (Regulation 22), and the present number is 39, it was open to the committee to select only one. The committee selected Professor H. G. Denham, M.A., M.Sc. (N.Z.), D.Sc. (Liverpool), Ph.D. (Heidelburg)." On the motion of Professor Park, seconded by Professor Speight, the report was unanimously adopted.

It was resolved on the motion of Dr Farr, seconded by Professor Kirk, that the procedure to be adopted in connection with the notification of subsequent vacancies in the Fellowship be left to the Standing Committee to arrange.

Incorporated Societies' Reports and Balance Sheets: The reports and balance sheets of the following incorporated societies were laid on the table:—Auckland Institute, for the year ending 31st March, 1933; Wellington Philosophical Society, for the year ending 31st October, 1932; Philosophical Institute of Canterbury, for the year ending 30th September, 1932; Otago Institute, for the year ending 30th November, 1932; Nelson Institute, for the year ending 30th September, 1932; Hawke's Bay Philosophical Institute, for the year ending 31st December, 1932.

Manawatu Philosophical Society: On the motion of Professor Segar, seconded by Mr Eliott, it was resolved that it be recorded with regret that the Manawatu Philosophical Society is no longer in active operation. The Board hopes that steps may soon be taken to resuscitate it.

Report of the Standing Committee for the Year Ending 31st March, 1933.

Meetings: Six meetings of the Standing Committee were held during the year, the attendance being as follows:—Mr B. C. Aston, Wellington, 6; Mr M. A. Eliott, Palmerston North, 1; Dr C. Coleridge Farr, Christchurch, 2; Mr G. V. Hudson, Wellington, 6; Dr E. Kidson, Wellington, 6; Professor Kirk, Wellington, 4; Dr E. Marsden, Wellington, 2; Dr P. Marshall, Wellington, 2; Mr W. R. B. Oliver, Wellington, 5; Professor H. W. Segar, Auckland, 1; and Professor D. M. Y. Sommerville, Honorary Editor, 5.

Board of Governors: Owing to the resignation of Dr L. Cockayne, F.R.S., C.M.G., a vacancy occurred in the Government representation on the Board of Governors. Mr M. A. Eliott, who had previously represented the Manawatu Philosophical Society, which has now ceased to exist, was appointed by the Government to fill the vacancy.

Under the Amendment Act, 1930, the Board of Governors has power to co-opt an additional member, and at the wish of the last annual meeting Dr P. Marshall, on the 3rd August, 1932, was appointed to the Board.

Finances: Several meetings of the Finance Committee have been held during the year, and strict control of the reduced finances has been kept. A limited amount has been authorised from time to time to be spent on each part of Volume 63, and the Secretary's salary has been still further reduced. Administration expenses have been kept as low as possible largely owing to the generous assistance of incorporated societies in paying their share of the pooled travelling expenses of members of the Board attending the annual meetings.

The grant of one thousand dollars (with favourable exchange amounting to £289 0s 2d) from the Carnegie Corporation of New York is being spent in publishing Volume 63, Part 1 (exclusive of the Proceedings), Part 2, and a portion of Part 3. A statement was forwarded to the Carnegie Corporation at its request showing how the grant is being utilised.

Publication Matters: The Otago Daily Times Company continues to print the Transactions, and although this firm increased its price for printing by 2s per page, it was considered that this increase was reasonable in view of the fact that the volumes being printed are so much smaller than those upon which the tender of this firm had been based. The first two parts of Volume 63 have been published, and Part 3 is in the press.

Sales: £29 9s was obtained from the sale of the Institute's publications during the year, and in accordance with a resolution of last year this amount has been credited to the Endowment Fund. In order to increase the sales of Transactions it was decided to accept annual overseas subscribers at 30s per annual volume instead of £2 as at present. The question as to whether this reduced annual subscription should be accepted from New Zealand subscribers who are not members of an incorporated society was referred to the societies for consideration. Auckland Institute was the only one which objected to the concession on the plea that it would militate against people becoming members of an incorporated society. No definite action has been taken in the matter, and a decision by the Board is desired.

Exchange List: On the recommendation of the Library Committee the following were added to the exchange list:—Massey Agricultural College; Department of Scientific and Industrial Research, London; Museo Nacional, Rio de Janeiro; Academy of Sciences, Allahabad; and Academy of Sciences, U.S.S.R.

Partial Sets: Partial sets of the Transactions were presented to Mr H. Hill, who had lost several copies in the Napier earthquake, and to the Research Ship Discovery II.

Library: The Library Committee recommended that £25 be expended on binding some of the more important publications in the Library. The binding was very satisfactorily done by a local firm, the N.Z. Home Libraries Bindery. An additional bookstack was also erected at a cost of £3 3s, and this has slightly relieved the congestion in the Library.

The Library is being used very freely by the staff and Honours students of the College, and many volumes have been posted to research workers residing out of Wellington.

Incorporated Societies: The following reports and balance sheets have been received:—

Wellington Philosophical Society for the year ending 30th September, 1932.
Philosophical Institute of Canterbury for the year ending 31st October, 1932.
Otago Institute for the year ending 31st October, 1932.
Nelson Institute for the year ending 30th September, 1932.
Auckland Institute for the year ending 31st March, 1933.
Hawke's Bay Philosophical Institute for the year ending 31st December, 1932.

Fellowship New Zealand Institute: Nine nominations for the Fellowship were received from the incorporated societies. These nominations were submitted for selection to the Fellows, and the voting papers have been considered by the Selection Committee, and its recommendation will come before the annual

Carter Bequest: Negotiations between the City Council and the Institute were during the year reopened at the former's request. Professor Kirk, convener of the Institute's Carter Bequest Committee, in a letter to the President of the Institute states:—

"You will remember that at the annual meeting in 1931 the committee set up to meet the City Council's Observatory Committee reported that the terms agreed upon by the Joint Committee for acquiring the City Telescope as a Carter Telescope and for building an observatory in which to house it had not been accepted by the City Council, and that it was concluded that negotiations were at an end.

"Later the City Council asked that negotiations might be reopened. The Standing Committee of the Institute thereupon set up again a committee of which I have the honour to be convener, and negotiations were renewed. The result has been that terms in keeping with those formerly agreed upon were formulated by the Joint Committee, and have now been endorsed by the City Council.

"The terms are as follows:—

"1. That the New Zealand Institute as Trustees of the Carter Bequest be granted a lease in perpetuity at a rental of 1s per annum (if demanded) of a one-quarter acre section in the Botanical Gardens, Kelburn, for the purpose of erecting there an observatory at a cost of approximately £3000 (Three Thousand Pounds).

"2. That the New Zealand Institute shall, when it has secured the necessary sanction by Act of Parliament, proceed with the building, and shall purchase from the City Council its telescope at a price not exceeding £500 (Five Hundred Pounds).

"3. That the governing body be the Carter Observatory Committee, which shall consist of five members, three being representatives of the New Zealand Institute as Carter Trustees, one being a representative of the Wellington City Council as providing the site, and one being a representative of the New Zealand Astronomical Society as providing the staff and upkeep.

"4. That the telescope be available for the use of the public for at least one night a week at a small charge to be fixed by the Carter Observatory Committee from time to time.

"Your committee recommends that the terms as set forth above be agreed to, that an empowering Act be sought at the forthcoming session of Parliament, and that a committee be set up to propose for sanction by the Standing Committee all necessary arrangements for carrying out the undertaking."

Hector Award: On the 2nd September, 1932, Dr Peter Buck wrote from New Haven, Connecticut, thanking the New Zealand Institute for the Hector Medal and prize, and stating: "I am greatly flattered at the honour which the New Zealand Institute has conferred upon me. When I saw the monument to Sir James Hector in the Kicking Horse Pass on my way through Canada I felt proud to think that I had shared in the monument that New Zealand had created to the memory of that great man." The medal was publicly presented to Dr Buck at a function at Yale University.

Hutton Award: On the 5th July, 1932, Dr P. Marshall, convener of the Hutton Award Committee, wrote: "I beg to inform you that the Hutton Award Committee has decided to recommend that the medal this year be awarded to Professor J. A. Bartrum, of Auckland, for research work in geology." The recommendation of the Award Committee was adopted at a meeting of the Standing Committee held on the 3rd August, 1932.

The medal was presented to Professor Bartrum at a meeting of the Auckland Institute held on the 5th September. Professor Segar, President of the New Zealand Institute, in making the presentation, referred to the researches in geology which had worthily earned the award to Professor Bartrum.

Hutton Grants: Three applications for grants from the Hutton Fund referred by the last annual meeting to the Standing Committee were considered at a meeting of the committee held on 15th June.

Mr L. C. King was granted £20 to enable him to conduct a field study of the tertiary rocks of the Awatere Valley, Marlborough.

Dr O. H. Frankel was granted £25 for the continuation of cytological research.

The Waitemata Harbour Survey Committee was granted £25 for the continuation of an ecological survey of the Waitemata Harbour.

The reports from these grantees are attached to the Research Grants report.

Two applications have been received this year for grants from the Hutton Fund, and in accordance with a resolution passed at last annual meeting have been considered by the Standing Committee. An application from Mr G. M. Thomson for a grant to enable him to purchase some literature and to pay for necessary transcriptions in connection with the preparation of an illustrated catalogue of the Crustacea of New Zealand is recommended for approval by the annual meeting. An application from Mr K. M. Rudall, of Massey College, for a grant of £5 to cover the cost of photographic material is also recommended for approval.

T. K. Sidey Summer Time Fund: The Declaration of Trust of the T. K. Sidey Summer Time Fund approved by the Board of Governors and by Sir Thomas Sidey at the last annual meeting has now been engrossed and executed.

On the 24th August, 1932, Dr Marsden, convener of the Summer Time Award Committee, reported that his committee could not agree in making an award, and he suggested that a new committee be set up. The following committee was thereupon set up by the Standing Committee, and its report will be presented at the annual meeting:—Dr P. Marshall (convener), Dr C. C. Farr, Professor H. W. Segar, Professor W. B. Benham, and Dr P. Clennel Fenwick.

Title of the New Zealand Institute: On the 14th July, 1932, his Excellency the Governor-General wrote stating that his Majesty the King had been graciously pleased to approve of permission being granted to use the prefix "Royal" in the title of the Institute. At a meeting of the Standing Committee held on the 14th August some discussion arose as to the form of the new title, and it was considered that members of the Board should have an opportunity of expressing their opinion on the matter. At the next meeting of the Standing Committee the replies from individual members of the Board were read. A large majority was in favour of adopting the title "Royal Society of New Zealand," and it was unanimously decided to make fresh application to his Excellency for permission to adopt that title. This has occasioned a good deal of delay, as it has been found necessary to again send to England for permission to use the amended title. When that permission is finally obtained an amendment of the Act will be necessary.

Australian and N.Z. Assoc. for the Adv. of Science: On the 10th May, 1932, a letter was received from the General Secretary of the A. and N.Z.A.A.S. in which he stated that the 1935 meeting of the Association will be held in Melbourne, and normally the Melbourne meeting is followed by a New Zealand meeting, and he asked whether New Zealand will wish to invite the Association to meet in New Zealand in 1937. It was ascertained that Auckland, whose turn it is for the next New Zealand meeting, would be prepared to organise the meeting provided Government assistance is assured. Subsequently the Right Hon. the Prime Minister promised that, "subject to financial conditions being in any way normal, the desired assistance will be forthcoming from the Government. It is understood that the total assistance involved in regard to printing, railway facilities, visits to places of scientific interest, and the printing of the report will be approximately £1000."

Dr Marshall, who attended the 1932 meeting, was therefore authorised to convey the invitation to the Association to meet in New Zealand in 1937.

At a meeting of the Standing Committee, held on the 15th June, Dr P. Marshall and Dr Raymond Firth were appointed to represent the New Zealand Institute at the 1932 meeting of the Association. Dr Marshall's report is attached.

Pacific Science Congress: Intimation was received that the Pacific Science Congress, postponed from 1932, is to be held in June, 1933, at Victoria and Vancouver. It is regretted that New Zealand will not be represented at the Congress.

Several papers have been forwarded for presentation at the Congress.

National Research Council: At a meeting of the Standing Committee held on the 3rd August the following were appointed to form the nucleus of the National Research Council:—Dr C. Coleridge Farr (convener), Professor Easterfield, Professor Kirk, Dr P. Marshall, and Mr F. W. Furkert. The convener, Dr Farr, will report to the annual meeting.

Apia Observatory: On the 29th November it was reported that Apia Observatory had been maintained by grants from the Carnegie and Rockefeller Foundations and a small grant from the New Zealand Government. The former grants were now exhausted, and there was danger of the Government grant being curtailed. The following resolution was forwarded to the Government:—"That this Institute desires to place on record its most lively appreciation of the value to world science and to New Zealand in particular of the researches in the domain of geo-physics carried out since its inception by the Apia Observatory, and its keen anxiety that the work of this important station should be continued permanently unimpaired in all its branches."

On the 10th March, 1933, a representative deputation waited on the Right Hon. the Prime Minister to ask for a continuation of the grant to the Apia Observatory, and were sympathetically received.

On the 24th March it was reported that the Rockefeller Foundation had consented to contribute 2500 dollars to the Apia Observatory.

Entomological Society of London: An invitation to the centenary meeting of the Entomological Society of London, to be held in May, 1933, was received. It was decided to ask Dr J. G. Myers and Mr E. Meyrick to represent the Institute.

International Geological Congress: An invitation to the International Geological Congress, to be held in July in Washington, was also received. It was decided to ask Dr J. M. Bell, at one time Director of the New Zealand Geological Survey, to represent the Institute.

Waipoua State Forest: On the 18th June the Institute of Horticulture wrote seeking the co-operation of the New Zealand Institute in endeavouring to secure the retention, intact, of the existing kauri areas in the Waipoua forest. A letter was forwarded to the Hon. Minister in charge of State Forests. The letter drew attention to the representations made in 1928 asking that the kauri forest be preserved for all time, and that no trees should be removed from the area except under the authority of and by the officers of the Forestry Department, and stated that on further consideration the New Zealand Institute now urges with regard to the block of 9000 acres containing the bulk of the remaining large kauri trees, that no removal of dead or mature trees be permitted, no regeneration experiments carried out, and above all, that no bleeding experiments or other utilisation experiments of any kind be allowed. In fact, that effective steps be taken at once to ensure that this special area shall remain permanently untouched.

The letter stressed the necessity for such measures being taken, pointing out the very great loss to the State in the last of the kauri being endangered.

The Hon. Minister replied on the 4th November that the representations of the Institute would receive careful consideration.

Arthur Pass National Park Board: The Lands Department advised that the appointment of the Arthur Pass Park Board was under consideration, and that provision could be made for representation of the New Zealand Institute. It was decided to recommend for appointment Professor R. Speight and Professor A. Wall to represent the Institute, and subsequently they were gazetted members of the Board.

Dominion Museum: At a meeting of the Standing Committee held on the 29th November some discussion took place on the scope of the Dominion Museum. Mr Aston pointed out that at present it was a Natural History and Ethnological Museum, and suggested that exhibits of agriculture and industry would widen interest in it. Mr Oliver, Director of the Dominion Museum, replied that at the present time no provision could be made in space for such exhibits, but that extension in that direction would be a desirable thing. Mr Oliver further stated that maintenance grants for the new museum would need to be considerably increased, and he made a suggestion as to how this could be effected. It was resolved that Mr Oliver and the Institute's representatives bring the matter before the Board of Trustees.

Portrait of Lord Rutherford of Nelson: A suggestion emanating from his Excellency the Governor-General that a copy of a picture of Lord Rutherford recently painted by Birley and presented to the Royal Society by the Fellows of that society be obtained for Wellington was considered, and subsequently it was decided to write to the Board of Trustees of the National Art Gallery and Dominion Museum suggesting that a certain gentleman be authorised to collect subscriptions to purchase this picture, which would be hung in the National Art Gallery, and asking for the Board's support in the matter. The Board of Trustees replied that whilst entirely sympathising with the object in view, it was considered that the time was not an opportune one for the raising of money, and suggested that the matter be deferred for reconsideration twelve months hence.

International Catalogue of Scientific Literature: The incorporated societies having expressed their willingness to assist in the compilation of classified references, the Smithsonian Institution was informed that the New Zealand Institute would co-operate in supplying material for the International Catalogue in the event of its being revived.

Natural Science in Schools: The report submitted to the last annual meeting by Mr G. M. Thomson and Professor Kirk was forwarded to the Hon. Minister of Education, to the Registrar of the University of New Zealand, and to the Director of Education. The Director referred the report to the secondary and technical school inspectors, and a discussion on this subject took place at the concluding session of the conference of primary, secondary, technical, and Native school teachers held in September, 1932, when it was decided that every effort should be made to increse the efficiency of the teaching of this subject.

Spectrohelioscope: At the last annual meeting a committee was set up to look into the matter of an offer of a spectrohelioscope which Dr Adams reported to that meeting had been made to New Zealand. Dr Kidson as convener of that committee reports that at a meeting of the committee a scheme for housing the spectrohelioscope was devised. Dr Adams secured from the Astronomical Section of the Wellington Philosophical Society a promise of sufficient funds to erect the proposed shelter. A cable was, therefore, sent to Dr Hale saying that use would gladly be made of the spectrohelioscope if provided. Although one had previously been offered, Dr Hale stated in his reply that unfortunately none was then available. It is probable that further efforts will be made either to obtain or to make an instrument for Wellington.

Mr G. V. Hudson's Book: On the 20th March, 1933, Mr G. V. Hudson wrote applying for financial assistance in the publication of an introductory book on "New Zealand Beetles and Their Larvae." This book is to contain 17 coloured plates. Mr Hudson asked that the New Zealand Institute purchase 100 copies at a cost of £100 and recoup itself by the sale of them as occasion offered. In view of the work that Mr Hudson has done and of his reputation as an author, it was decided with the approval of the Finance Committee to purchase 100 copies at £100, the selling price per copy to be determined later.

Walter Burfitt Prize: The secretary of the Royal Society of New South Wales wrote intimating that the Walter Burfitt Prize had been awarded to Dr Charles Kellaway for his contribution, "Snake Venoms and Their Effect on Human Beings." The Institute wrote congratulating Dr Kellaway.

The foregoing report of the Standing Committee was then taken clause by clause. On the motion of Mr Aston it was resolved that the report of the Carter Observatory Committee be deleted from the report. He stated that the report had not been considered by the Standing Committee, and that it would come up later on in the Agenda.

With this amendment the report was adopted.

Arising out of the Report—

Subscribers to the Transactions: On the motion of Mr Eliott, seconded by Mr Pycroft, it was resolved to accept at 30s per volume annual subscribers to the Transactions resident in New Zealand but non-members of an incorporated society.

Honorary Member: An election for one honorary member was held, and resulted in the election of Sir Guy Marshall.

Vacancies in Honorary Members' List: The following vacancies in the list of honorary members were declared:—Professor J. W. Gregory, Sir Ronald Ross, Sir John A. Thomson, and Professor Johannes Schmidt.

Hector Award: The President read the report of the Hector Award Committee as follows:—"The committee recommends that the Hector Award for this year be made to Dr W. N. Benson, Dunedin, and Dr J. Marwick, Wellington. That a medal be issued to each recipient, and that the prize be divided equally.—(Signed) R. Speight, Convener."

The report was unanimously adopted.

Amount of Hector Prize: On the motion of Mr Eliott it was resolved that the amount of the Hector Award be £40 each recipient.

T. K. Sidey Summer Time Award: The President then read the report of the convener of the T. K. Sidey Summer Time Award Committee, which was as follows:—"I beg to report as follows in regard to the proposed award of the Sidey Medal. Four of the five members of the committee are in favour of recommending that the medal be awarded to Mr G. V. Hudson. The fifth member of the committee thinks that Mr Hudson's work on summer time does not come within the scope of the Trust Deed.—(Signed) P. Marshall, Convener."

The meeting went into committee.

After some discussion the President moved the adoption of the committee's report.

On its being put to the meeting the following voted:—For the motion: Professor Segar, Mr Aston, Dr Marshall, Mr Hudson, Mr Oliver, Professor Park, Mr Eliott. Against the motion: Dr Farr, Dr Kidson, Mr Pycroft, Dr Marsden, Professor Kirk, Professor Speight, Professor Easterfield.

The casting vote of the Chairman was given in favour of the motion. Dr Marsden's amendment therefore lapsed.

Professor Segar congratulated Mr Hudson on the award.

The meeting was resumed in open Board.

Carter Bequest: The President read the report presented by the Carter Observatory Committee. Mr Aston moved that the report be referred to the Standing Committee for consideration and report to next annual meeting. He stated that the report had not been before the Standing Committee. Professor Kirk, convener of the Carter Observatory Committee, replied that he did not consider that the matter should be delayed in that manner. Although the written report of the committee had not actually been before the Standing Committee, the contents had been known to members of the Standing Committee, and the terms were practically those which had been agreed to by the Board at the annual meeting in 1927. Dr Kidson supported Professor Kirk, stating that the procedure proposed by Mr Aston would delay any action for eighteen months. It was asked whether there was any special reason for deferring action. Mr Aston replied that he had received information that the price of telescopes had been greatly reduced, and he considered that further time was necessary to obtain additional information regarding prices. He stated that he was of the opinion that the Carter Observatory

Committee had agreed that there should be a six months' option. Professor Kirk said that he had no recollection of any such agreement having been suggested.

Mr Hudson stated that since attending the Carter Observatory Committee meetings he had learned that prices of telescopes had come down, and he did not want the Institute to make a bad bargain. Dr Kidson said that there was no evidence that the bargain would be a bad one. Dr Marsden considered that the project should be proceeded with along the lines of the report. Professor Easterfield stated that while something more in keeping with the testator's wishes had been hoped for, it seemed the attainment was so remote that the Board would be wise to agree to the next best thing along the lines of the committee's recommendation. Professor Segar urged delay so that in time an observatory of which New Zealand could feel proud could be erected. Professor Kirk pointed out that negotiations had been reopened with the City Council in all good faith and with the consent of the Standing Committee, and he hoped that if the Board did not wish to proceed along the lines of the recommendations of the committee, it would pass a resolution to that effect and not allow the matter to be merely delayed. Dr Marshall raised the question of the suitability of the suggested site.

It was finally decided to refer the report to the Standing Committee.

At a later stage the following motion, moved by Professor Kirk and seconded by Mr Hudson, was carried:—"That the Institute instruct the Standing Committee as to whether it wishes any further steps to be taken in negotiation with the Wellington City Council or oherwise in the direction of setting up a Carter Observatory."

Consequent upon the motion, it was further resolved on the motion of Professor Kirk, seconded by Dr Marsden:—"That the Institute authorises the Standing Committee to continue negotiations if they think it desirable with the Wellington City Council for purchase of the city telescope or some other, and to take such steps as it may think desirable to establish a Carter Observatory on lines such as those indicated in the report submitted to the Institute."

Still further, on the motion of Dr Marsden, seconded by Dr Farr, it was resolved:—"That in the matter of the proposed Carter Observatory the Standing Committee be empowered to take all necessary action to give effect to its resolutions following negotiations with the City Council, etc."

Honorary Treasurer's Report.

The balance sheet for the twelve months ending 31st March, 1933, shows a balance of assets over liabilities of £1067 11s 11d, as compared with £799 15s 3d on the 31st March, 1932.

The Income Account discloses that the statutory grant was £500, a reduction of £250 from the previous year. Levy and sales produced only £57 5s, as compared with £251 19s 2d, but on the other hand an unexpected although welcome addition to revenue was a grant from the Carnegie Corporation of

New York of one thousand dollars, which, together with a favourable rate of exchange, produced £289 0s 2d.

Turning to the expenditure side, owing to the reductions in the statutory grant, drastic cuts had to be made in cost of printing the Transactions. This has been reduced to £262 5s 4d during the past year, as compared with £1500 a few years ago. The printing of Part 2 of Volume 63 has been completed, the cost being £131 plus postage. The Finance Committee has authorised the expenditure of £240 on Parts 3 and 4. The Levy for Volume 63 has not yet been called up.

Notwithstanding the diminution in receipts, the rigid economy carried out by the Finance Committee has placed the finances of the Institute in a sounder position to-day than they have been for many years.

The various Trust Accounts administered by the Institute maintain their satisfactory condition. The Carter Bequest Capital Account now stands at £8946 12s 7d as compared with £8504 12s 7d twelve months ago, and the Endowment Fund is £948 4s 6d as against £748 2s. Shortly before the close of the financial year all the funds invested in New Zealand Government Inscribed Stock and Post Office Inscribed Stock were converted in accordance with the Government loans conversion scheme into 4% Inscribed Stock. In compliance with the New Zealand Loans Act, 1932, the total amount of the funds thus invested has been divided equally between the various maturity dates, 1940, 1946, 1949, and 1955. The amount converted stands in the balance sheet at £12,994 6s 2d. As a result of this conversion, revenue from interest will be reduced by approximately £153 per annum.

The books and accounts have as customarily been kept in an excellent way by the Secretary.

M. A. Eliott,

Honorary Treasurer.

NEW ZEALAND INSTITUTE.

Statement of Receipts and Expenditure for Year Ending 31st March, 1933.

Receipts.

	£	s.	d.
Balance as at 31st March, 1932	1,389	10	3
Annual Grant	500	0	0
Carnegie Corporation of New York Grant	289	0	3
Levy Volume 62 (balance)	22	15	6
Sales of Publications	29	9	0
Travelling Expenses from Incorporated Societies	44	12	0
Research Grants Refunded	3	5	4
Trust Funds transferred to Bank of New Zealand	565	13	2
Interest P.O. Savings Bank	32	4	2
Carter Bequest Interest	456	13	4
Hector Memorial Fund "	65	3	9
Hutton Memorial Fund "	75	3	0
Carter Library Legacy "	9	1	2
Hamilton Memorial Fund "	2	9	1
Endowment Fund "	40	11	9
T. K. Sidey Summer Time Fund "	29	5	5
T. K. Sidey Summer Time Fund (contribution)	0	10	0
	£3,555	7	1

Expenditure.

	£	s.	d.
Otago Daily Times Company, Vol. 62 (3/4), 63 (1)	251	4	1
Stationery	6	6	9
Bethune and Company (Transactions purchased)	5	10	0
Salary	255	0	0
Travelling Expenses	69	19	9
Subscription Inter. Scientific Union	3	15	9
Petty Cash	15	4	8
Charges (Insurance, Bank Com. Audit)	6	3	0
Library Shelving	3	3	0
Library Binding	20	13	6
Gazette Notice—Fellowship	0	7	0
Trust Accounts—Audit Charges	2	0	0
Research Grants Instalments	43	6	6
Hutton Grants Instalments	60	0	0
Hector Prize and Charges on Draft	65	14	2
Trust Funds Invested	641	17	6
T. K. Sidey Summer Time Fund Deed	2	12	6
Interest credited direct to Trust Accounts	638	5	9
Balance as under	1,464	3	2
	£3,555	7	1

	£ s. d.	£ s. d.
Bank of New Zealand	£300 13 11	
Less Unpresented Cheques	43 11 1	
	257 2 10	
Post Office Savings Bank	1,199 0 8	
Petty Cash in Hand	7 19 8	
		1,464 3 2
		£1,464 3 2

M. A. Eliott, Hon. Treasurer.

NEW ZEALAND INSTITUTE.

Statement of Liabilities and Assets as at 31st March, 1933.

Liabilities.		£	s.	d.
Carter Bequest	Capital Account	8,946	12	7
Hector Memorial Fund	,,	1,184	18	1
Hutton Memorial Fund	,,	1,314	8	0
Hamilton Memorial Fund	,,	60	4	0
Carter Library Legacy	,,	100	0	0
T. K. Sidey Summer Time Fund	,,	508	10	4
Endowment Fund	,,	948	4	6
Carter Bequest	Revenue Account	279	14	11
Hector Memorial Fund	,,	116	14	7
Hutton Memorial Fund	,,	262	13	5
Hamilton Memorial Fund	,,	5	19	10
Carter Library Legacy	,,	67	6	2
T. K. Sidey Summer Time Fund	,,	66	0	9
Endowment Fund	,,	76	11	4
Library Fund	,,	156	5	10
Research Grant Fund	,,	216	9	11
Balance of Assets over Liabilities		1,067	11	11
		£15,378	15	8

Assets.		£	s.	d.
Inscribed Stock converted		12,994	6	2
Bank of New Zealand		257	2	10
Post Office Savings Bank		1,199	0	8
Petty Cash in Hand		7	19	8
Outstanding Accounts		32	4	1
Carter Bequest	P.O.S.B. Account	281	9	11
Hector Memorial Fund	,,	117	19	7
Hutton Memorial Fund	,,	278	18	5
Hamilton Memorial Fund	,,	66	8	10
Carter Library Legacy	,,	67	13	8
T. K. Sidey Summer Time	,,	75	11	10
		£15,378	15	8

The Audit Office having examined the Balance Sheet and accompanying Accounts required by law to be audited, hereby certifies them to be correct.

G. F. C. Campbell,
Controller and Auditor-general.

NEW ZEALAND INSTITUTE.

Revenue Account for the Year Ending 31st March, 1933.

Expenditure.	£	s.	d.
Printing and Stationery	262	5	4
Salary	255	0	0
Travelling Expenses—Institute's share	9	14	6
Charges	13	1	9
Petty Cash	15	4	8
Sales credited to Endowment Fund	29	9	0
Balance	1,067	11	11
	£1,652	7	2

Income.	£	s.	d.
Balance at 31st March, 1932	799	15	3
Annual Grant	500	0	0
Carnegie Corporation of New York Grant	289	0	2
Administration Trust Accounts	6	6	9
Sale of Publications and Levy	57	5	0
	£1,652	7	2

New Zealand Institute Trust Accounts.

Carter Bequest for the Year ending 31st March, 1933.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
	£	s.	d.		£	s.	d.
To Interest Invested ..	441	15	0	By Balance 31/3/32	266	11	7
„ Administration Expenses	1	15	0	„ Interest ..	456	13	4
„ Balance .. .	279	14	11				
	£723	4	11		£723	4	11
				By Balance ..	£279	14	11

Hector Memorial Fund for the Year ending 31st March, 1933.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Prize (Dr Buck)	60	0	0	By Balance 31/3/32	118	18	6
„ Charges Draft	5	14	2	„ Interest .	65	3	9
	65	14	2				
„ Engraving Medal ..	0	8	6				
„ Administration Expenses	1	5	0				
„ Balance	116	14	7				
	£184	2	3		£184	2	3
				By Balance	£116	14	7

Hutton Memorial Fund for the Year ending 31st March, 1933.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Grants paid .	60	0	0	By Balance 31/3/32	249	3	5
„ Administration Expenses	1	5	0	„ Interest .	75	3	0
„ Engraving Medal ..	0	8	0				
„ Balance	262	13					
	£324	6	5				
				By Balance			

Carter Library Legacy for the Year ending 31st March, 1933.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Administration Expenses	0	7	6	By Balance 31/3/32	58	12	6
„ Balance	67	6	2	„ Interest .. .	9	1	2
	£67	13	8				
				By Balance			

Hamilton Memorial Fund for the Year ending 31st March, 1933.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Administration Expenses	0	5	0	By Balance 31/3/32	5	0	3
„ Half Interest to Capital	1	4	6	„ Interest	2	9	1
„ Balance	5	19	10				
	£7	9	4		£7	9	4
				By Balance	£5	19	10

T. K. Sidey Summer Time Fund for the Year ending 31st March, 1933.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Administration Expenses	1	14	3	By Balance 31/3/32	49	8	11
„ Engrossing Deed	2	12	6	„ Contribution	0	10	0
„ One-tenth Interest to Capital, 1930-33	8	16	10	„ Interest ..	29	5	5
„ Balance	66	0	9				
	£79	4	4		£79	4	4
				Balance	£66	0	9

Endowment Fund for the Year ending 31st March, 1933.

Dr	£	s	d.	*Cr.*	£	s.	d.
To Interest Invested	200	2	6	By Balance 31/3/32 .	176	3	11
„ Administration Expenses	1	15	0	„ Interest .	40	11	9
„ Balance	76	11	4	„ Interest from General Account .	32	4	2
				„ Sale of Publications .	29	9	0
	£278	8	10		£278	8	10
				By Balance ..	£76	11	4

The Hon. Treasurer moved the adoption of his report and the balance sheet and financial statements. He also asked the Board to confirm the conversion of the Trust Funds in accordance with the following letter from the Registrar of Inscribed Stock:—

The Secretary,
New Zealand Institute,
Wellington.

Dear Madam,—With reference to your letter of the 23rd ult., and your interview with one of my officers in regard to the various holdings of stock in the name of the New Zealand Institute, conversion of which is now being effected in terms of the applications submitted, I have to confirm that for the purpose of adjustment of premium on conversion the applications submitted must necessarily be aggregated, and, furthermore, in view of the provisions of Section 37 of the New Zealand Loans Conversion Act, 1932, no notice of the Trusts in respect of which stock is held can be entered in the register or be receivable by the Registrar.

To meet the Institute, however, the Treasury will be prepared to arrange separate inscriptions under several maturity dates to which the conversion stock has been allocated. Premiums on conversion of the Institute's holding total £46 11s 7d, calculated in accordance with the aggregation of the applications as mentioned above, and in this connection new stock to the nominal value of £45 will be issued and a refund of the fractional amount of £1 11s 7d made to the Institute on or after the 1st July next.

The following stock has been allocated to the various maturity dates in accordance with the prospectus in the amounts shown hereunder:—15th January, 1940, £3410; 15th February, 1946, £3410; 15th April, 1949, £3410; 15th June, 1955, £3415.

In regard to the matter of inscription of new stock this will be arranged as under:—1940 Stock, one inscription, £3410; 1946 Stock, one inscription, £3410; 1949 Stock, two inscriptions, one for £2640 and the other for £770; 1955 Stock, five inscriptions as under: £600, £100, £955, £510, £1250.

Inscription in the manner indicated will enable you to allocate the respective amounts in accordance with the arrangement under which the various parcels of stock are held by the Institute.

Yours faithfully,
(Signed) A. D. PARK,
Registrar of Stock.

The Hon. Treasurer's report and financial statements were adopted, and on the motion of Professor Kirk the conversion of the Trust Funds as set out confirmed.

REPORT OF HONORARY EDITOR.

The publication of the Transactions has proceeded somewhat slowly during the past year, and although the matter for Volume 63 is all arranged for, there will be some delay before the parts are all published. Part 1, consisting of 41 pages of Proceedings and 79 pages of papers, with 18 plates, was issued in October, 1932, and Part 2, containing 156 pages and 10 plates, in February, 1933. Part 3 is in the hands of the printer, and Part 4 is arranged for.

The complete Appendix, containing the Act, Amendment Acts, Regulations, Trust Deeds, List of Members, and Exchange List which has not appeared since Volume 60, it is proposed to print in Volume 64, so as to embody the amendments and additions which will by that time have become effective.

D. M. Y. SOMMERVILLE, Hon. Editor.

On the motion of Mr Eliott the report of the Hon. Editor presented by Professor Sommerville was adopted.

REPORT OF THE HONORARY LIBRARIAN.

Since the last report of the Library a certain amount of relief to the state of congestion has been afforded by the erection of an additional bookstack It is hoped that this will enable the periodicals to be accommodated in a more or less accessible state until the more ample provision of the new Museum is available.

Some further sets of periodicals have been bound, and this very necessary work should be continued as long as funds are available for the purpose.

The Library is one of the most important assets of the Institute, and full use cannot be made of it until (a) it is properly housed; (b) the sets of periodicals are all bound and a fund provided for binding each volume as soon as it is complete; and (c) a complete catalogue is prepared and made available for the use of readers. These are essential objectives, the attainment of which must be continually stressed. D. M. Y. SOMMERVILLE, Hon. Librarian

On the motion of Dr Marshall, seconded by Mr Eliott, the report of the Hon. Librarian presented by Professor Sommerville was adopted.

RESEARCH GRANTS REPORT.

Dr R. S. Allan in 1930 was granted £30 for research on tertiary brachiopoda. On the 5th May he reported that he had carried out field work, and obtained collections of brachiopoda from several localities. The collections have been studied in part, and the results published in Volumes 62 and 63 of the Transactions, and the fossils now available will provide the raw material for further contributions to the knowledge of our tertiary palaeontology and stratigraphy. The whole of the grant has been expended.

Mr G. Archey in 1926 was granted £40 for research on New Zealand Chilopoda. On the 29th April he reported that he had been unable yet to finalise his report. Further collecting in the King Country, Coromandel, Clevedon, the Waitakeries, and the Waikato district has been done and has added new forms, and the examination of type specimens from the United States has caused a very worth while delay. Expenses during the year amounted to 21s, exhausting the grant.

Mr B. C. Aston in 1928 took over from Dr Malcolm £9 16s 7d for research on pukateine. On the 7th April he reported that during the year further supplies of bark had been forwarded to Professor Barger, who has written from Edinburgh University that Dr Schlittler was just attacking the problem of the constitution of lauropukine, the third alkaloid of pukatea bark, of which he had been able to isolate some 15 grams. On the physiological side of the investigation, Dr Fogg, of the Otago Medical School, intends to resume this work. As Professor Barger has refunded the expenses incurred in forwarding material to him, the balance of the grant stands at £7 12s 11d.

Mr G. Brittin in 1919 was granted £20 for a research in fruit tree diseases. On the 18th April he reported that he had continued to obtain results from his experiments, and he forwarded a full report of the work accomplished up to that date with the conclusions arrived at, which may be summarised as follows:

(1) That bud-dropping and die-back of peach trees is apparently due to late growth in the autumn, consequently the wood is not mature when the first frosts make their appearance.

(2) That great care must be exercised when using artificial manure, the forcing effects of which are generally to promote too late a growth in the autumn, besides causing a later maturing of the crop.

(3) That a cover crop every three years has proved the most satisfactory way of keeping the trees healthy and strong and fit to bear regular crops of fruit.

(4) That a late spraying in the autumn of lime-sulphur 1-100 before the leaves fall, with regular sprayings of atomic sulphur or lime-sulphur 1-150, will keep under control both the brown rot and shot-hole fungus in any ordinary season.

(5) That careful pruning combined with judicious heading back will cause the trees to give regular crops of fruit, besides preventing much infection of the trees by silver blight.

There is an unexpended balance of £2 11s 9d.

Mr A. E. Brookes in 1928 was granted £40 for study of the coleoptera of the islands off the Auckland coast. On the 29th March he reported that during the past year practically all his spare time had been devoted to mounting and classifying the specimens obtained. Altogether over 1000 specimens had been dealt with. Six hundred were taken on the Little Barrier Island representing 152 species, and 400 specimens from the Hen and Chicken Island representing 85 species, and it is probable that there will be several new species to record. There is an unexpended balance of £1 16s.

Mr J. W. Calder in 1930 was granted £30 for research in the vegetation of Arthur Pass. On the 18th April he reported that the work had progressed satisfactorily, two visits being made to the area at Arthur Pass. Most of the time was spent in locating from old prints and photographs areas photographed 35 years ago. Work is being continued as opportunity offers, and a paper dealing with the salient features of the vegetation changes has been published in the Journal of Ecology. The whole of the grant has been expended.

Miss L. Cranwell in 1930 was granted £20 for study of the ecology of marine algae. On the 19th April she reported that intensive work on selected bays at Anawhata was continued, and a considerable amount of field work was done over a larger area than last year. Special attention was paid to localities where fresh-water streams or seepage entered, and where moving sand was an important factor. During the last year a big collection of bottled and pressed material has been made. The mounted specimens are being arranged in two series—(a) systematic and (b) according to their ecological grouping in herbarium boxes purchased for the purpose. There is an unexpended balance of £9 1s 5d.

Dr G. H. Cunningham in 1929 was granted £25 for a mycological survey of Tongariro National Park. On the 24th April he reported that during last season he was unable to visit the Park, and consequently no fungi were collected. No expenses were incurred, and there is a balance of £18 1s.

Dr O. H. Frankel in 1929 and 1930 was granted £42 12s for cytological research. On the 26th April he reported that the study of the cytology of genus Hebe has progressed considerably. At present the chromosome numbers of nearly 50 species are known. Different chromosome numbers have been found for forms belonging to the same species, e.g., for varieties of Hebe salicifolia. A case of species formation by chromosome restitution has been found in a hybrid swamp, *H. buxifolia* x Traversii, the new form possessing the added parental numbers. A similar mechanism apparently is responsible for several other species formations which, on morphological grounds, had been attributed to hybridization by Drs Cockayne and Allan *(H. laevis* and *H. evenosa)*. Grantee has a balance in hand of £8 0s 2d.

Miss E. M. Heine in 1930 was granted £15 for research on pollination of New Zealand plants. She reported on the 7th April that since her last report she has been accumulating more data, and she is now only waiting for a further identification of insects by the Museum Entomologist before she can publish a full account of the results.

Dr J. K. H. Inglis, who between 1923 and 1930 was granted £125 for research on essential oils of native plants, reported on the 18th April that work on the essential oil of *Dacrydium Biforme* was continued by Mr J. W. Shields. Special attention was directed to the solid Diterpene which is common to this oil, to that from *Dacrydium Colensoi*, and to that from *Phyllocladus Alpinus*. Work has also been started on the constitution of Karaka nuts. The expenditure during the year was only 17s 5d, leaving a balance in hand of £4 10s 5d.

Mr A. W. B. Powell in 1925 was granted £50 for a survey of the Molluscan Fauna of Manukau Harbour. He reported on 12th April that a further series of dredgings was made, and in conjunction with others taken previously will suffice to supply the information required concerning the bottom conditions of the area. The shore work is still progressing as opportunity offers, but there still remain considerable areas yet to be investigated. Three papers prepared during the year have been sent in for publication in the Proceedings of the Malacological Society of London. There is an unexpended balance of 15s 11d.

Mr H. F. Skey in 1927 was granted £175 in addition to the balance left by Captain Isitt for upper air research. He reported on the 19th April that with the aid of the second aerological theodolite the observational work is being continued almost daily free of expenditure from the grant. The first theodolite purchased is being used in Auckland for observational work. With the improvements in reliability of air-plane travel the air services will probably soon be extended, and with this in view it seems advisable to continue the observations of upper air currents. There is an unexpended balance of £48 1s 4d.

Waitemata Harbour Survey Committee was in 1925 granted £65 for an ecological survey of the Waitemata Harbour. Mr Powell, who is secretary of the committee, reported on the 12th April that further series of dredge stations have been established, and much of the material obtained has been worked over and distributed to those engaged upon the various groups. The polychaete material has been named by Professor Benham, who intends writing a report on the whole of the polychaete material collected during the course of the investigations. The hydrographical and meteorological report is being prepared by Mr W. K. Hounsell, who already has made numerous salinity and hydrogen-ion concentration tests for the various parts of the area. Miss Cranwell has made further investigations with the seaweeds, and Mr Falla has collected a large amount of data concerning the feeding habits of the sea birds of the area, and is making an investigation into the plankton content of the seawater. Dr Uttley has the bryozoan material to report upon, and Mr W. F. Bennett, of Perth, has supplied identifications of crabs, and intends publishing a note on a species new to New Zealand that was dredged by the committee. He himself has prepared extensive lists of the mollusca of the area. Three papers based on the findings of the committee have been published. This research is also assisted by a Hutton grant of £25, £10 of which was paid during the year, leaving a total unexpended balance of £21 15s 7d.

Dr G. H. Uttley in 1928 was granted £35 for research on bryozoa. He reported on the 24th April that the receipt of recent literature and collections of additional recent specimens have necessitated a considerable amount of revision of the papers already prepared.

Hutton Research Grants.

Mr F. J. Turner was granted £30 at the annual meeting in 1932 to enable him to undertake a geological expedition to the south-west portion of Otago. He reported that the expedition went to Hollyford Valley in January, 1933. After ten days in the field he was recalled to Dunedin, and the work was left in the hands of Messrs Mackie and Service, who were quite capable of carrying out the survey. Mr Turner returned later to the field to complete certain investigations (at his own expense), and the results of the expedition will be embodied in a paper which will be submitted to the Institute for publication within the next two years.

Mr Christensen, who was granted £25 for collecting hybrids at Hanmer, reported that he had been unable to utilise the grant last year, and has asked that it may be available this year

Mr L. C. King was granted £20 for a field study of tertiary rocks in the Awatere Valley. He reported on the 21st February that during the summer he spent ten and a-half weeks and traversed an area of 250 square miles, most of which was geologically mapped. Collections of fossils were made and brought in for study. The examination of the rocks belonging to the Awatere series is practically complete, and cursory observations have also been made on the older rocks of the district. He proposes to prepare the results of the investigation when the classification of the fossils is completed.

Dr O. H. Frankel and ***Waitemata Harbour Survey Committee*** reports are embodied in the research grants report given on pages xvi and xvii.

On the motion of Dr Kidson, seconded by Dr Farr, the report was adopted

TONGARIRO NATIONAL PARK BOARD.

Report of the New Zealand Institute's Representative on Park Board.

During the year ending 31st March, 1933, two meetings of the Park Board have been held in Wellington, both of which were attended by your representative.

The question whether the collection of botanical specimens, seeds, or live plants should be allowed was brought up by an application from an intending visitor from Auckland to the Park It was pointed out that collections could quite well be made outside the Park boundaries. As a matter of general policy the Board will not grant permits to remove plants from any portion of the Park. So far as is at present known, there is no plant peculiar to the Park, and all plants that occur there can be found outside its boundaries in the adjacent mountains, swamps, or forests.

Section 15 of the Tongariro National Park Act, 1922, provides, *inter alia*, that every person is liable to a fine of £50 who, without being authorised by the Board, wilfully breaks, cuts, injures, or removes any or any part of any wood, tree, shrub, fern, plant, stone, mineral, furniture, utensil, tool, or thing of any kind

The above provision appears to be sufficient to safeguard the amenities of the Park if enforced by the local honorary rangers and supported by public opinion, but there is also urgent need for a paid ranger to patrol the Park regularly, and when there are funds available for this purpose it is hoped that such an appointment will be made

An application for permission to cut firewood and dead timber from the Park was, in accordance with this Institute's resolution at the last annual meeting, opposed by your representative and refused by the Board. Permits to cut wood have all been cancelled now, but a permit to cut dead wood for firing has been granted to the Prisons Department at the old milling area at Waikune, near Erua, under strict supervision.

The better definition of the route from the Ohakune track to the Chateau track by means of painted poles has been completed to the general satisfaction of climbers.

Two honorary rangers have been appointed during the year—Mr Blyth, the well-known climber, who is also a member of the National Park Board, resident at Ohakune, and Mr Young, a member of the Chateau staff. It is hoped that these appointments may help to bring about a better attitude of the local settlers and of visitors towards the preservation of the natural features of the Park.

An adequate camping ground has been set aside for motorists in an area near the Chateau.

B. C. Aston.

18th April, 1933.

The report of the Park Board was on the motion of Mr Aston, seconded by Mr Pycroft, adopted.

Dr Marshall asked if any survey had been taken to ascertain to what extent the heather was spreading in the park. Mr Aston replied

that it was perhaps spreading in the wet marshy areas of the park, but it was not spreading in the higher, drier parts at all.

Mr Pycroft asked if it would not be possible to eradicate the heather. Mr Aston replied in the negative.

Professor Kirk asked whether the rangers in the park were honorary rangers or were paid for their services. On Mr Aston's replying that they were honorary, Professor Kirk suggested that the Institute should urge that as soon as possible paid rangers be appointed.

Arthur Pass Park Board: Professor Speight asked if a report on the Arthur Pass Board was required, and being answered in the affirmative, promised that one should in the future be supplied.

NATIONAL ART GALLERY AND DOMINION MUSEUM BOARD OF TRUSTEES.
REPORT BY VICE-PRESIDENT

During the year ending 31st March, 1933, seven meetings of the full Board have been held and attended by two representatives of this Institute, namely, the President's deputy (either Professor Kirk or Dr Marshall) and the Vice-president, also by Mr Oliver, Director of the Dominion Museum and member of this Board.

The most important work during the year was the decision arrived at by the meeting on 15th November, 1932, presided over by the Prime Minister, to accept the tender of the Fletcher Construction Co, Ltd, for building the main Art Gallery and Museum building at a cost of £160 182 5s 7d. The contractors have made a start with the preliminary work, and it is expected that the building will take three years to erect It is to be particularly noticed that the pink Putaruru stone of a vitric tuff, common to the Waikato basin, has been selected for the stone work required in the building, this stone having been found to be quite suitable in the completed Campanile building.

The peat kauri gum collection secured through the good offices of the Minister of Internal Affairs, Hon. Mr Young, a member of the Board, will be housed in the new Museum, and will be a decided acquisition and also an exhibit of great value.

Pictures: A suggestion from his Excellency the Governor General that a replica of the painting of Lord Rutherford, by Birley, a New Zealander, painted by him through the Royal Society, should be purchased by public subscription for the Art Gallery was considered by the Board, but action was postponed for a year.

An offer of a picture of Mount Cook from a local source had also to be declined, as there was no storage accommodation for pictures at present.

Deputy Chairman: It has been found necessary to suggest that the Governor introduce amending legislation providing that in the absence of the Chairman (Prime Minister) and Deputy Chairman, the Minister of Internal Affairs should act as Chairman, and if all three are absent the Chairman of the Finance Committee shall take the chair at the Board meetings.

B. C. ASTON, Vice-president.

The adoption of the report of the representative on the Board of Trustees was moved by Mr Aston and seconded by Dr Marshall, who stated that it was a matter for congratulation that New Zealand stone was being used in the facings of the new buildings.

Management Committee of the Dominion Museum: On the motion of Mr Aston, seconded by Mr Eliott, it was resolved that the nomination of a Museum Committee of Management be made by the Standing Committee, if necessary to forward to the Board of Trustees of the National Art Gallery and Dominion Museum.

Institute of Horticulture.

Report of the New Zealand Institute's Representative.

The Institute of Horticulture has suffered a severe blow in the sudden death of Mr A. R. Stone, a secretary whose place it will be very difficult to fill.

The work of the Institute for the year has been on the lines of the previous reports, but in addition the following will be noticed as an extension of the Institute's work:—

Plant Patents: The Institute is taking an interest in formulating measures which will provide protection to the raisers of new plants, and also for the establishment in connection therewith of a statutory nomenclature Board.

Forest Preservation: Consideration of the preservation of the Waipoua Kauri Forest received attention during the year, and a conference was held on the matter at which delegates from the Forestry Department, Agricultural Department, and Forestry League gave their opinions. Representations to the proper authorities are being made by the Institute which it is hoped will be conducive to the preservation of this rare type of forest. Other matters receiving consideration were the preservation of native forests, supervision of scenic reserves, and the importation of plants and animals. In connection with the latter, it was decided to support the following resolution passed by the Forestry League:—

> "Importation of Birds and Animals.—That in view of the past disastrous experience in connection with the introduction into New Zealand of birds and animals other than domestic, the Government be urged to absolutely prohibit any further importation."

Growing of Vegetables by the Unemployed: The Institute took an active part in furthering the Government's vegetable growing scheme whereby areas in the city suitable and vacant could be utilised by the unemployed under suitable supervision for growing vegetables.

Monthly meetings have been held during the year and attended by your representative.

B. C. Aston.

Mr Aston, representative of the Institute on the Institute of Horticulture, moved the adoption of the report, which was seconded by Mr Pycroft and carried.

Report of the Polar Year Committee for the Year ended 31st March, 1933.

In April, 1932, a cable was received from Dr la Cour, President of the International Polar Year Commission, asking if the New Zealand Committee could use at Macquarie Island, Christchurch, or elsewhere a set of "quick run" magnetographs if provided by the Commission. The magnetographs referred to are of a type developed by Dr la Cour for the Polar Year work. They are run twelve times as fast as the ordinary magnetographs, enabling changes in the earth's magnetism to be recorded in detail and timed accurately.

It was ascertained that to install the magnetographs at the Christchurch Observatory's magnetic station at Amberley and to tabulate the records for publication would cost approximately £200. Dr la Cour's offer was accepted, and an appeal made to the public for funds. With the assistance of the incorporated societies in Auckland, Wellington, Christchurch, and Dunedin £165 9s 10d was collected. The state of the fund will be gathered from the balance sheet.

The instruments have been received and installed by Mr H. F. Skey, Director of the Christchurch Magnetic Observatory, at Amberley, where they are working satisfactorily.

Dr la Cour stated in a letter written on the 6th December, 1932, that "Some very interesting records have already been received. Thus as far as concerns the quick-run magnetic records the material up to date shows clearly the exact simultaneity over the earth of the sudden commencement of magnetic perturbations and various categories of oscillations, among which some oscillations are recorded with approximately the same amplitude, for instance, at the Azores and in Copenhagen, while other oscillations are very frequent in the Arctic regions, but of much smaller extension. Further, there are some still

quicker oscillations with time of oscillation of about 1 second, the occurrence of which could be recorded. Such oscillations occur simultaneously at stations some few hundred kilometres apart."

It is thus clear that the observational material being collected will enable the variations in terrestrial magnetism to be analysed with far greater accuracy than hitherto. A great deal is, therefore, sure to be learnt regarding their causes. Any such discoveries will have very important bearings on other branches of geophysics.

In addition to the magnetic work it has been possible to arrange that determinations of the height of the Heaviside layer should be carried out. For this purpose, apparatus has been loaned by the Carnegie Institution of Washington, and is now being installed at Victoria College, Wellington, under the direction of Professor Florance and Dr M. A. F. Barnett.

Special meteorological work is being done at the Meteorological Office, Wellington, and the Christchurch Magnetic Observatory. It is understood also that the New Zealand Astronomical Society's Solar Committee is recording solar and auroral phenomena.

New Zealand's contribution to the Polar Year scheme will thus not be altogether negligible.

EDWARD KIDSON,
Secretary, N.Z. Polar Year Committee.

MAGNETOGRAPH FUND BALANCE SHEET.

Receipts.	£	s.	d.	*Expenditure.*	£	s.	d.
By Subscriptions . . .	165	9	10	Expenses connected with Installation, Amberley ..	15	13	5
				Cable, Postage, etc. ..	1	1	2
				Cash in Hand ..	0	5	9
				Balance in P.O.S.B. ..	148	9	6
	£165	9	10		£165	9	10

The report of the Polar Year Committee was moved by Dr Kidson, seconded by Professor Speight, and carried.

GREAT BARRIER REEF COMMITTEE.

REPORT OF REPRESENTATIVE.

The committee met three times during the year 1932.

All the apparatus and equipment left by Dr Yonge's expedition has been handed to the committee for storage or sale.

The Secretary, Land Administration Board, advised that Hinchinbrook Island has been proclaimed a reserve for a National Park.

It has been decided to resume survey on the Reef by a party working from a shore base, and a camp was established on Molle Island in July last.

An investigation of Peel Island in Moreton Bay showed a considerable amount of coral. Coralline algae played a large part in binding together the detrital coral fragments.

The financial statement shows a balance of £2255.

W. R. B. OLIVER,
New Zealand Institute Representative.

The report of this committee was moved by Mr Oliver and adopted.

WARD ISLAND.

REPORT OF REPRESENTATIVE ON DOMAIN BOARD.

Since the appointment of a Board two meetings have been held and two visits paid to Ward Island. Both trips have been due to the courtesy of Mr A. Holmes, who made his launch available on each occasion.

On September 10, 1932, members landed for about half an hour and made general observations on the state of the vegetation and the prevalence of rabbits, some of which were killed. Subsequently poison was laid by the Department of Agriculture. On the second visit, November 5th, the construction of a path

to the upper portion of the island was begun. No evidence of rabbits having been recently on the island was seen, and it is believed that they have been exterminated by the poison. With the absence of rabbits it is confidently expected that scrub vegetation will gradually replace the grass and ice plant. It is intended, however, to sow seeds and plant shrubs to hasten the growth of a suitable plant covering.

W. R. B. Oliver,
New Zealand Institute Representative.

The report of the Ward Island Domain Board was moved by Mr Oliver and adopted.

Observatories Committee.

The Observatories Committee has practically ceased to function as an Observatories Committee during the year, as it was unnecessarily large and cumbersome, and a new committee consisting of Dr Kidson, Mr A. T. Walsh, and Dr C. Coleridge Farr was set up by the Council of Scientific and Industrial Research. This committee has been active in looking after the interests of the various observatories under the New Zealand Government control. In this connection and with the support of the Royal Society and authorities in England it brought before the notice of the Government the great international importance of Apia Observatory with a view to assuring its financial stability.

It is hoped that its representations will be successful.

C. Coleridge Farr.

The report of the Observatories Committee was moved by Dr Farr, seconded by Mr Eliott, and carried.

Apia Observatory: On the motion of Dr Farr, seconded by Mr Eliott, it was resolved:—"That this Board expresses the hope that the Government will take such steps as will place the work of the Apia Observatory on a permanently assured basis."

Australian and New Zealand Association for the Advancement of Science.

Report of Sydney Meeting, August 17-24, 1932.

The meeting was attended by a large number of representatives from all the Australian States, and it seemed to be regretted by all that New Zealand had not a larger delegation. The meetings were held in the University of Sydney, and there was a good attendance at all of the sectional meetings.

In the various sections the different papers that were read had rarely any reference to New Zealand. There was, however, a combined meeting of the Geology and Geography sections to discuss the question of the former eastern extension of the Australian continent.

The two meetings of the Council of the Association were well attended. At the initial meetings an invitation to hold the 1937 meeting at Auckland was received with hearty applause. As the delegate of the New Zealand Institute, I stated that the Association would be cordially welcomed, and that it would find an agreeable and convenient town for the meeting.

The delegates were formally welcomed by the Lord Mayor of Sydney at the Town Hall. All the members were entertained by his Excellency the State Governor at a garden party at Government House. The local State Government entertained all members at a harbour excursion. There was much private hospitality, which enabled members to engage in informal discussions.

P. Marshall.

The report was on the motion of Dr Marshall, seconded by Mr Hudson, received.

National Research Council: Dr Farr, convener of the committee forming the nucleus of the National Research Council, reported as follows: "In accordance with the instructions given at the last annual meeting of the New Zealand Institute, your committee, consisting of Professor Kirk, Dr Marshall, Professor Easterfield, Dr Farr, and Mr Furkert, has taken steps to select the following:—Mr J. E. L. Cull, Mr F. W. Grainger, Mr F. T. M. Kissell for Engineering; Dr D. Miller, Dr G. H. Cunningham, and Professor Benham for Biology; Professor J. A. Bartrum, Professor W. N. Benson, Dr J. Henderson for Geology; Professor D. M. Y. Sommerville, Dr E. Kidson, Dr E. Marsden for Mathematics and Physics.

"The committee also recommends that the rules of the Australian National Research Council to be found in the annual report of December, 1932, be taken as the basis of the rules for the New Zealand National Research Council.

"The committee feels that unless some method can be found for financing the work of the Research Council the body cannot function with any effectiveness, and therefore it recommends that until such finance is available no further steps be taken."

On the motion of Dr Farr, seconded by Dr Marshall, the report was adopted.

Applications for Hutton Grants: An application from Mr G. M. Thomson for £30 to assist him in the preparation of an illustrated catalogue of the Crustacea of New Zealand and from Mr K. M. Rudall, of Massey College, for a grant of £5 in connection with a zoological research on Little Barrier Island were, on the recommendation of the Standing Committee, approved on the motion of Mr Aston, seconded by Mr Pycroft.

Notices of Motion were then taken:—

Agenda of Annual Meetings: On the motion of Mr Pycroft, seconded by Dr Marsden, it was resolved that a copy of the Agenda of Annual General Meetings be sent to the secretaries of incorporated societies.

Portrait of Lord Rutherford: On the motion of Dr Farr, seconded by Dr Kidson, it was resolved that the thanks of the Board of Governors be accorded to Mr G. L. Stewart for his offer of help in collecting funds for a portrait of Lord Rutherford, and that he be informed that the Board hopes that the matter will be taken up again later.

Title "Royal": On the motion of Mr Oliver, seconded by Mr Hudson, it was resolved that the Standing Committee be authorised to take action necessary to put into effect the following changes following on approval being given by his Majesty to adopt the title "Royal Society of New Zealand":—

1. To draw up consequential amendments to the New Zealand Institute Act.
2. To alter the title F.N.Z. Inst. in the Fellowship Regulations.

Cawthron Institute: On the motion of Mr Pycroft, seconded by Professor Kirk, is was resolved: "That it be a recommendation that this meeting urges the Government to give the Cawthron Institute such financial support as will enable it to carry on its very valuable research work, which is in the interests of the Dominion as a whole."

Dr Marsden wished it recorded that he did not vote on this matter.

Pacific Science Congress: Mr Oliver proposed and it was seconded by Professor Easterfield: "That it be a recommendation to the Government that an invitation be forwarded to the Pacific Science Congress to hold a meeting in Wellington in 1939 or 1940, and that the Standing Committee wait on the Prime Minister to place the matter directly before the Government."

Some discussion took place in regard to this resolution. Mr Oliver pointed out that if an invitation was to be extended it would require to be cabled by the Government to the Pacific Science Congress being held in Vancouver in June of this year, as invitations had to be considered two Congresses previously.

It was stated that the holding of a Pacific Science Congress involved a very large sum, as it was usual for hospitality to be extended to delegates and their wives, including free railway facilities and excursions to places of interest and in addition the printing of the report. It was considered most improbable that the Government would commit itself to providing the necessary grant or considering the matter in the limited time available.

The motion was withdrawn.

Natural Science in Schools: Professor Kirk informed the Board that some good had resulted from the report on Natural Science in Schools presented at last annual meeting, in that the Academic Board had recommended that Biology (with Botany as an alternative) should be included in the subjects for the Entrance Scholarship.

Science Congress: The question as to whether a Science Congress should be held next year was discussed, and it was decided to refer the matter to the incorporated societies and authorise the Standing Committee to act.

Levy Volume 61: On the motion of Mr Eliott, seconded by Dr Kidson, it was resolved that the levy be fixed at 5s per volume.

Election of Officers: President, Professor R. Speight; Vice-President, Mr B. C. Aston; Hon. Treasurer, Mr M. A. Eliott; Hon. Editor, Professor D. M. Y. Sommerville; Hon. Librarian, Professor D. M. Y. Sommerville; Hon. Returning Officer, Professor H. W. Segar; Managers' Trust Accounts, Messrs Aston and Eliott; Representative Institute of Horticulture, Mr B. C. Aston; Representative Great Barrier Reef Committee, Mr W. R. B. Oliver.

Election of Committees:

Research Grants Committee: Re-elected, Dr Hilgendorf (Chairman), Professor R. Speight, Dr Denham, Dr Farr, and Mr C. E. Foweraker.

Hector Award Committee: Dr Farr, Professor Sommerville and Dr Evans.

Library Committee: Professor Sommerville, Professor Kirk, and Dr Cotton.

Finance Committee: Messrs Eliott, Aston, Drs Marsden and Kidson.

Fellowship Selection Committee: Dr Marsden (Convener), Dr L. Cockayne, Dr P. Marshall, Dr W. P. Evans, and Mr W. R. B. Oliver.

Votes of Thanks: On the motion of Dr Marsden, a very hearty vote of thanks was accorded to the retiring President, Professor Segar, for his work during the past two years.

A hearty vote of thanks was also accorded to the Vice-President, and reference was made to the efficient way in which he had managed the affairs of the Standing Committee in the absence of the President.

Votes of thanks were also accorded to the Hon. Editor, Professor D. M. Y. Sommerville, the Hon. Treasurer, Mr M. A. Elliott, the Secretary, Miss Wood, and the Victoria University College Council for the use of the Lecture Hall for the meeting, and to the Press.

Date and Place of Next Annual Meeting: It was decided that the next meeting be held in Wellington in May, the exact date to be fixed by the Standing Committee.

PRESIDENTIAL ADDRESS

Delivered at the Annual Meeting at Wellington, on 18th May, 1933,
By Professor H. W. Segar, M.A., F.N.Z.Inst.

Gentlemen,—

As usual, my first duty is to refer to the losses we have sustained by death since we last met. Unfortunately, our honorary membership has suffered severely. No less than three of our honorary members have passed away during the past year in the persons of Professor J. W. Gregory, D.Sc., F.R.S., F.G.S., elected in 1920; Sir Ronald Ross, elected in 1929, and Sir J. Arthur Thomson, M.A., LL.D., elected in 1928.

Professor Gregory held the chair of Geology in the University of Glasgow from 1904 to 1929, but a little previously to this period he had been Director of the civilian scientific staff of the British Antarctic Expedition of 1901, following which he became Professor of Geology and Mineralogy in the University of Melbourne and Director of Geological Survey in Victoria. These offices associated him closely with the scientific work of this part of the world, and made him eminently suitable in this respect for election to our honorary membership. During his life he visited many parts of the world on various expeditions, and received many honours from numerous societies.

Amongst the names of those who have conferred really great benefits on the human race the name of Sir Ronald Ross looms large. He was the discoverer of the life-history of the malarial parasite and a pioneer in the treatment of tropical disease. He has been described as not only the conqueror of malaria, but as the man who made one-third of the world inhabitable. He had a strong inclination for the writing of verse. In one of his poems, referring to his discovery of the causal relation of the mosquito to malaria, he wrote:—

> "I know this little thing
> A myriad men will save."

This prognostication has been amply fulfilled. Yet he died a comparatively poor man. He used up his resources on his work for mankind, and ultimately a fund had to be raised to save him from dire poverty. The New Zealand Institute has been greatly honoured in having had Sir Ronald Ross amongst its honorary members.

Sir John Arthur Thomson was lately Regius Professor of Natural History at the University of Aberdeen, and served that University for 31 years. His name as a scientist was exceedingly well known. A great contribution to this result was the extent and quality of his popular writings on modern knowledge in his own and various other fields; but he also wrote several solid treatises of a biological and zoological character that have gained wide acceptance and use, as well as numerous zoological papers, especially on Alcyonarians.

The losses through death amongst the ordinary membership of the affiliated societies have not been heavy; losses have probably been greater as a consequence of resignations resulting from the present

financial straits of so many members. We may mention here, as amongst the deceased, Mr G. E. Way, who was for many years Hon. Auditor and a life member of the Philosophical Institute of Canterbury, and Mr Charles Rhodes, member of the Auckland Institute and Museum, who was also from its foundation a member of the Council of Scientific and Industrial Research.

Members of the Board will, I am sure, join with me in regret for the recent severe illness of Sir Thomas Sidey and Mr G. M. Thomson and in a heartfelt desire for their speedy and complete recovery.

Reports of the Standing Committee.

I think it is time that the Board should give expression to its recognition of the excellence of the reports that we get annually from the Standing Committee. These reports are full, complete, clear, and admirably drawn up. If any one individual is mainly responsible for the very satisfactory character of the reports, he deserves the thanks of this Board. These reports go a long way, by reason of their fulness and completeness, towards making an address from the President almost a superfluity, and it must often be a matter of some difficulty for a President to find any subject concerning the activities of the Institute during the year which has not already been adequately treated in the report of the Standing Committee submitted to the Governors.

As to matters reported on in this year's report, Governors will notice with satisfaction that his Majesty the King has been graciously pleased to approve of permission being granted to use the prefix " Royal " in the title of the Institute. Steps would no doubt have been taken promptly to obtain the amendment to the Act necessary to establish the new title, but for the decision of the Standing Committee, arising from afterthoughts and after adequately sounding the opinions of members of the Board, that a more satisfactory complete title would be " Royal Society of New Zealand " rather than " Royal New Zealand Institute." This decision involved delay while further permission was sought. Though the Institute (for such we must still call it, at least for a time) has behind it a high tradition and a record of valuable work well and faithfully done, the proposed new title would, from its associations, indicate more clearly the special work of the Society, and distinguish us more clearly from the numerous " Institutes " that exist. The proposed new title would bring its own traditions from the Old Country, and, in itself, would do much to urge the Institute to increase its efforts to promote the interests of Science.

Finances.

Turning to the finances of the Institute, it seems reassuring to be told in the Honorary Treasurer's report that the finances of the Institute are " in a sounder position to-day than for many years," even although this is the result of " the rigid economy carried out by the Finance Committee." This constitutes a silver lining to the

cloud, but we must not let it dazzle us so completely that we cannot see the cloud. We must realise what this rigid economy consists of. It is mainly a rather ruthless cutting down of the Transactions, an economy we do not desire to have to continue for any great length of time. On the other side of the account, we have also to remember, we had last year a contribution of £289 resulting from a Carnegie Corporation grant of $1000. We can hardly regard this as other than a windfall or look on the Carnegie Corporation as a steady source of income. We shall be very fortunate if it be otherwise. The position then is clearly that, if we are to restore the Transactions of the Institute to their former standing, we require an assured income substantially greater than we can at present command. Further, if our research workers are to receive the encouragement they deserve we require a restoration of the research grant. It is not right that scientists, in addition to giving freely of their time, talents, and energy, should be sometimes also heavily out of pocket by reason of their researches Though some researches will no doubt be carried out in the absence of financial assistance, others may be seriously delayed or abandoned. We have read often how other nations, when up against adverse circumstances, have turned to education and research with confidence as the best means of restoration. I hope our nation is not altogether devoid of this outlook. But, unfortunately, as things are, education and research, especially the latter, have been severely deprived of resources, either by loss of Government support or by other circumstances.

Research.

For we are not the only institution to have suffered in these times. All of us must have regretted what we have read in the press from time to time of the losses and restrictions of work suffered by such institutions as Massey College and the Cawthron Institute. Now the increasing complexity of the world's industry and affairs demands a higher proportion of educated people, and these educated to a higher degree. And to the progress of the material welfare of the people research is essential. There is no end to the problems that have to be solved. To use the words of Sir J. Arthur Thomson, whose recent death we lament to-day, " Whenever one is more or less solved, another crops up. The world becomes more and more intelligible, but there are always peaks beyond peaks. And besides puzzles which will disappear like cloudlets in the light of more facts, and besides half-solved problems, many of the fundamentals are elusive and mysterious."

The nation is not true to its best interests that allows either its educational or research facilities to be starved. Since we last met, the North American Review, writing of the operations of the Guggenheim Fund of $4,500,000, whose chief object is the financing of research and other creative work, remarks: " In a given length of time this assuredly will have its effect. This fund *represents a faith in intellect as an investment.* While the factories hum and the steel mills roar, the lamp of the student is kept lit and his mind is eased in the hope that a return will soon be forthcoming."

In Canada, again, the report of the National Research Council for 1930-1 states that, although industry has been under a cloud, the annual expenditure of the Council in assisting research amounted to no less than $550,000; and " Nature " remarks that " it is evident Canada is building up a corps of research workers whose influence on the future of her industries is likely to be most important."

The large number of cases in which the chairmen of British banks have been emphasising the importance of research in their recent addresses to shareholders almost suggests a concerted scheme to educate the British public on the question. This should hardly be needed. The extraordinary developments that have taken place in some British industries, arising directly from research, and especially in the case of textiles and metals, ought to have been sufficient, if anything were needed, to inspire in Britain also that same " faith in intellect as an investment." Those of us who have the interests of New Zealand at heart will at least hope that any such similar faith that exists here will be quickened, and not damped, by the adverse circumstances of the time. Research is not a luxury to be indulged in merely when we are prosperous; it is a necessity to be most insisted on just when we find it most difficult to provide the means. If our faith in intellect as an investment were what it ought to be, and equal to what we find in many other places, the provision for research would not be the cause to suffer first, and to suffer most, from the advent of diminished prosperity.

Conclusion.

I cannot conclude without expressing regret that circumstances during the year have prevented me from attending more than one of the meetings of the Standing Committee held during the year. Under these conditions Mr Aston, as Vice-president, has proved a tower of strength. By prompt and full correspondence we have kept in touch with one another, and he has succeeded in keeping me fully conversant with the business of the committee. It was partly to provide for such conditions that the office of Vice-president was instituted, and I can assure the Board that, in this respect, the office has fully justified itself. I thank Mr Aston heartily for his assistance, and apologise for the extra work my absence from meetings has imposed on him.

Vegetation of the Bealey River Basin.

SUPPLEMENT TO LIST OF SPECIES (1929), WITH NOTES.

ROBERT M. LAING, M.A., B.Sc., F.N.Z.Inst.,
and H. W. GOURLAY, M.Sc.

[*Received by Editor, 27th October, 1932; issued separately, May, 1934.*]

WE are well aware that the work of Drs. Cockayne and Allan has shaken to its foundations the splendid taxonomic work of Cheeseman; and that no list of species of any New Zealand district can be considered altogether satisfactory which does not take into account the presence of hybrids and epharmonic varieties. Nevertheless, it is necessary in the first place to follow to some extent Cheeseman's system if the ground is to be prepared for a fuller and more modern investigation of the area under consideration; and we have therefore in this paper in many cases identified species on the basis of Cheeseman's Flora, though we know that we are dealing with aggregate species, or with forms whose exact type is unknown. Obviously it would be impossible for us in many cases to do otherwise; for a more exact research would demand a complete study of the species dealt with in all its forms throughout New Zealand. Such a study is impracticable in a paper intended merely to form a basis of further research in a given district. We hope, however, if time and opportunity offer, to extend our work to a fuller consideration of the forms dealt with, to bring our knowledge of them as far as possible into harmony with modern taxonomic and ecological methods. We have already begun such a study in connection with the smaller-leaved species of *Pittosporum*, and it is proving exceptionally interesting.

At present we intend only to add to the list already published (1929, *Trans., N.Z. Inst.*, 59, p. 715) such species as have been identified in the district subsequently to its publication. We propose in some cases to give descriptions of forms rather than actual names that may be misleading. The attempt to force into the Procrustean bed of the Manual, a form which obviously is too wide or too narrow for such a process, can only create further difficulties for subsequent observers, since it is quite clear that some races of plants in the Pass are distinct from those found elsewhere, or at least differ in certain respects from those included by Cheeseman in his description. When, however, a name is given without comment, we consider that the plant referred to may readily be included within the four corners of Cheeseman's prescription.

Further, we have not restricted this list to the Upper Bealey River basin, but have included some species found in the watershed, only to the south of Halpins Creek. We have, however, so far not made any complete investigation of the lower area, nor of many of the valleys near the snow line. Mr Gourlay has paid much attention to the grasses, and the result is a largely extended list of these.

Species Not Hitherto Recorded.

Hymenophyllaceae.

Hymenophyllum rarum R. Br.
Rocks above Punch Bowl, 3000ft.

H. sanguinolentum Swartz.
On dry tree trunks in the forest, Halpins to settlement.

H. Cheesemanii Bak.
Rocks near Avalanche Creek, 2500ft.

Trichomanes Lyallii (?) Hook. and Bak.
Rocks near beginning of Avalanche Peak track.
Very much depauperated, and without the marginal hairs.

Polypodiaceae.

Dryopteris punctata (Thunb.) C. Christen.
Rocks by roadside, near Avalanche Peak track.
A much reduced form collected by Miss M. Finlayson.

Asplenium flaccidum Forst. f.
Rocks in forest.
A much depauperated form, usually under 25 c.m. in length, and more or less erect and rigid.

A. Hookerianum Col. forma.
Moist rocks of creeks, 2000ft.
A form approaching, but not altogether agreeing with, var. *Colensoi*.

A. flabellifolium Cav.
Rocks in bush, Lower Bealey.

Polypodium diversifolium (R. Br.) Willd.
Rocks in forest, near Lower Bealey Road.

Gramineae.

We have to thank Dr H. H. Allan for revising the grasses collected by us. Some of his notes are appended.

Hierochloe Fraseri Hook. f. var. *recurvata* Hack.
In tussock 3000 to 4000ft, south side of Punch Bowl Creek and at the top of the Pass.
Apparently quite a distinct form.

Alopecurus geniculatus L.
Swamp near Kennedy's.
The spikes are dark purplish, shorter than usual, with rather long awns.

Deyeuxia avenoides (Hook. f.) Buch.

Twin Creeks, near road.

D. avenoides var. *brachycantha* Hack.

Grass bank, north of Rough Creek.

D. Forsteri (Roem. and Schult.) Kunth. var. *Lyallii* Hack.

"Comes into the group considered by Cheeseman to be var. *Lyallii*, but is not the *Agrostis Lyallii* of Hooker."—H. H. A.

D. setifolia Hook. f.

On rocks near the White Bridge, Peg-leg Flat, and elsewhere.

Agrostis Dyeri Petrie var. *aristata* Hack. in Chees.

Roadside near settlement.

Dichelachne crinita (Forst. f.) Hook f.

A solitary specimen by the roadside near Halpins.

Trisetum antarcticum (Forst. f.) Trin.

A fairly common plant in moist tussocky places in scrub.

T. antarcticum var. *diffusum* Allan and Zotov (sp. ined.)

Mingha Valley.

Trisetum tenellum (Petrie) Allan and Zotov (sp. ined.).

Mingha River bed.

Allan and Zotov consider this variety should be raised to specific rank.

Trisetum Cheesemanii Hack.

River bed, 2500ft.

Danthonia setifolia (Hook. f.) Ckn.

River bed near settlement, Lower Bealey, Punch Bowl, and elsewhere.

Danthonia setifolia forma *minor* Allan et Zotov (sp. ined.).

Punch Bowl Creek.

With bright orange stamens. "This may be only a habitat form." H. H. A.

D. semiannularis R. Br. var. *nigricans* Petrie.

Punch Bowl Creek.

Koeleria novo-zelandica Domin.

Punch Bowl Creek.

K. novo-zelandica Domin forma.

Roadside near Halpins.

According to Dr Allan, this approaches f. *parvula* Domin, "a plant of quite uncertain status."

Poa Novae Zelandiae Hack. forma *humilior* Hack.

Shingle slip, Upper Otira.

"Has typical leaf section of *P. Novae Zelandiae* and corresponds to var. *Wallii* (Petrie in Chees.). Whether a good variety or a habitat form remains to be investigated." H. H. A.

P. Novae Zelandiae var. *subvestita* (?) Hack.

Lower Bealey.

"Differs very slightly in leaf section from typical form, makes some approach to variety *subvestita* (var. *subvestita* was collected by Cockayne on Arthurs Pass)." H. H. A.

P. anceps Forst. f.

Top of Pass.

"Has the leaf section of *P. anceps*, and comes into the South Island group included under that name by Cheeseman." H. H. A.

P. seticulmis Petrie.

McGraths Creek.

"This belongs to the unresolved *P. pusilla-seticulmis* group It is not typical *P. pusilla*, which occurs on the moraine at the head of the Otira Gorge We class it under *P. seticulmis* in the meantime." H. H. A.

P. pusilla Berggr.

Behind railway cottages, roadside.

P. Colensoi Hook. f.

Edwards Stream, Upper Bealey, at 4000ft, and elsewhere. In various forms.

P. Kirkii Buch.

Bush behind railway cottages; common on the roadside near Halpins.

"This group is ill-defined, and contains a great number of forms." H. H. A.

Festuca rubra L.

Near top of Pass, possibly introduced, but it has a very wide distribution in the district.

Festuca sp.

On shingle in creeks near Kennedy's. Collected by Miss R. B. Weavers.

"A remarkable form, deserving of further study, has the leaf section of *F. erecta*!" H. H. A.

Agropyron scabrum (Lab.) Beauv.

Lower Bealey River bed, Mingha River.

Fairly common, and responding in various ways to differences in habitat.

Asperella gracilis T. Kirk.

Punch Bowl Creek.

CYPERACEAE.

Scirpus Aucklandicus (Hook. f.) Boeck.
In wet swampy ground, bush behind railway cottages.

Uncinia rubra Boott.
Lower Bealey.

Uncinia fusco-vaginata Kukenth.
Damp places by roadside.

Carex Petriei Cheesem.
Near the roadside at Halpins Creek.

Carex ternaria (Forst. f.) var. *pallida* Cheesem.
A variety closely approaching this is found in swamps at the junction of the Mingha and Bealey.

Carex Gaudichaudiana (Hook. f.) Kukenth.
Swamp at junction of Mingha and Bealey.

C. Gaudichaudiana (Hook. f.) Kukenth. var. *humilior* Kukenth
Swamp at junction of Mingha and Bealey.

C. Raoulii Boott.
Roadside near Kennedy's.

C. Oederi Retz. var. *cataractae* (R. Br.) Kukenth.
Roadside below Halpins.
A somewhat depauperated form.

JUNCACEAE.

Luzula Traversii (Buchen.) Cheesem.
Mingha River bed.

LILIACEAE.

Chrysobactron sp.

Headwaters of the Bealey, 4500ft, and summit of the Pass, in damp, stony ground.

It is impossible to identify this with any recognised species. A description is attached.

A herb, 7 mm. to 10 mm. in diameter at the base, 35 cm. to 60 cm. high, leaves numerous, all radical, 5 mm. to 12 mm. broad, 10 cm. to 30 cm. long, concave above, broadly ensiform, gradually tapering upwards, spreading and recurved, glaucous green, obtuse to acute at the tips, fleshy, glabrous. Scape terete, usually exceeding the leaves, curved, 30 cm. to 60 cm. long, 4 mm. to 6 mm. in diameter, inflorescence corymbose, lower peduncles 2 5 to 5 cm. in length, each peduncle bearing at its base a concave, acuminate, green bract, white on the edges, 1 cm. or more in length, upper peduncles shorter so that inflorescence is a corymb 5 cm. to 7·5 cm. in length, with a

few flowers below the surface of the corymb. Flowers 12 mm. A solitary plant from the top of the Pass (3000ft) with polygamo-dioecious flowers beginning to open, was apparently not corymbose; but the flowers were in a dense raceme. The leaves were 25 mm. broad towards the base, and generally much stouter than in the Bealey Glacier plant. The flowers were also about 25 mm. in diameter when expanded. This obviously more closely approaches *C. Rossii* of the Southern Islands. Flowers 12 mm. in diameter, bright yellow, polygamo-dioecious. A few flowers are apparently perfect; but some or all of the anthers are wanting in others, and in others again the stigma is apparently undeveloped. Segments of the perianth oblong-linear, concave, obtuse, and spreading, 6 mm. to 16 mm. long, completely free. Stamens hypogynous, of the male flowers, usually shorter than but occasionally equalling the segments, ripe capsules not seen.

It is obvious that until a full collection of the chief New Zealand forms is obtained, it is inadvisable to name this form. In its polygamo-dioecious flowers it clearly belongs to the *C. Rossii-Gibbsii* group; but in its definitely corymbose inflorescence it apparently differs from both of these. It is larger than *C. Gibbsii*, but smaller than *C. Rossii*.

ORCHIDACEAE.

Pterostylis Banksii R. Br. (forma).

P. australis Hook. f. (forma).

P. graminea Hook. f. (forma).

In bush, sides of creek, 2500ft.

None of these species is typical of their representatives elsewhere. They occur in a great variety of forms impossible to classify satisfactorily. Intermediates between *P. Oliveri, P. Banksii*, and *P. graminea* are all to be found. Colenso, *Trans. N.Z. Inst.* (1883), p. 338, (1886) p. 270, (1899) pp. 488-489, (1896) p. 611, has divided the forms of this group into a number of distinct species, but till an intensive study of the varieties occurring throughout New Zealand is made, it seems scarcely worth while to discriminate more closely.

Some sketches made by Mrs Brownlee of the Arthurs Pass plants accompany this note. (Fig. 1.)

Thelymitra pachyphylla Cheesem.

In small quantity near Halpins, 2200ft.

This seems rather an unexpected locality for this West Coast plant, but the specimens exactly fit the description.

T. longifolia Forst.

Rocky ground, edge of bush, below Kennedy's.

Microtis unifolia (Forst. f.) Reichenbach.

By roadside, 2000ft.

URTICACEAE.

Urtica incisa Poir.

Scrub, Lower Bealey.

CARYOPHYLLACEAE.

Scleranthus biflorus (J. R. and G. Forst.) Hook. f

River flats, lower Mingha.

CRUCIFERAE.

Nasturtium fastigiatum Cheesem.

Avalanche Peak, 5900ft

Cardamine depressa Hook. f.

Rocky crevices, Upper Bealey, 4500ft.

Cardamine sp.

A species of *Cardamine* occurs on the moraines and rocks close to the snowline, which seems to be distinct from any hitherto recorded from the mainland of New Zealand It is very close to and possibly the same as the Auckland and Campbell Island, *C. glacialis* var. *subcarnosa*, though perhaps a somewhat smaller plant. It has the same stout perennial rhizome, and somewhat fleshy habit; but the flowers are always white, and scarcely so large as those described by Cheeseman (1909, p. 399)* for the southern variety. The pods are numerous, about 2 cm. long, 1 mm. in breadth, flat above, more or less concave below, with a short style. The fruits may differ from the sub-antarctic variety in some respects, so we consider it not safe to identify the species.

PITTOSPORACEAE.

Pittosporum anomalum Lg. and Gy. (sp. ined.).

Jack's Hut and top of Pass.

P. divaricatum Ckne.

Rough Creek to Waimakariri, Edwards Stream, and Mingha .

The *P. divaricatum* of the previous list is now *P. crassicaule* Lg. and Gy. (sp. ined.). This is the true *P. divaricatum* Ckne. of the Cass.

P. crassicaule (Ckne.) Lg. and Gy. (sp. ined.).

Abundant in the forest from about 2300 to 2800ft.

ROSACEAE.

Acaena fissistipula Bitter.

Punch Bowl Creek, below the fall, 2500ft (R. M. L. and W. R. B. O.).

* Sub-Antarctic Islands of New Zealand, Vol. II.

Thymeleaceae.

Drapetes villosa Cheesem. var. *multiflora* Cheesem.
South side of Punch Bowl, 4000ft, and elsewhere in boggy ground.

Onagraceae.

Epilobium tenuipes Hook. f.
Flat at the mouth of the Mingha.

Epilobium Hectori Haussk.
Swamp in settlement (behind " Rockery Neuk ").

E. pedunculare A. Cunn. var. *minutiflorum* Ckne.
Blimit Cirque, 4500ft.

Umbelliferae.

Hydrocotyle novae-zealandiae D. C. var. *montana* T. Kirk.
Swampy ground, 4000ft

Aciphylla Lyallii Hook. f.
Bealey River bed, near settlement.

We are in much doubt as to the separateness of the Aciphyllas at Arthurs Pass. We have collected specimens from the settlement (2400ft) up to 5500ft on Avalanche Peak. The plants at the lower level must be called *A. Lyallii*. They are much stouter, their leaves are narrower, much more rigid and coriaceous, and the inflorescence longer and the spines not only more than proportionately longer, but much stiffer, than in plants from a higher altitude; and these in the main, according to Cheeseman (1906) pp. 663 and 664, constitute the differences between *A Lyallii* and *A. crenulata*. The question therefore arises whether the low forms are not habitat states of one species. The plants become smaller as one ascends, until at 5500ft they are not more than 3 to 4 inches high. According to Cheeseman (loc. cit.), *A. Lyallii* is a plant of altitudes from 3500 to 5500ft, and *A. crenulata* is found from 2500 to 5000ft. These facts give little guidance, but Cockayne (1928) p. 302, includes *A. crenulata* with a number of high mountain species. *A. Lyallii* is believed to be found from the Rangitata Mountains to Dusky Sound, and *A. crenulata* from Mount Arthur plateau, Nelson, to the Mount Cook district. The only method of solving the problem of relationship would be to obtain seeds from different districts and grow them in the same situation, and compare the resulting plants.

It is a question whether the *A. Lyallii* of Cheeseman is the *A. Lyallii* of Dusky Sound.

Anisotome filifolia (Hook. f.) Ckn. and Lg.
Floor of bush, Edwards Stream. (Collected by Miss E. Campbell.)

Epacridaceae.

Cyathodes acerosa R. Br.
Scrub, mouth of Edwards Stream, and roadside below Halpins Creek.

APOCYNACEAE.

Parsonsia capsularis (Forst. f.) R. Br. var. *parviflora* H. Carse.
Jack's Hut and Peg-leg Creek.

BORAGINACEAE.

Myosotis australis R. Br.
Creek below Kennedy's.

Myosotis sp.
Avalanche Peak, among rocks, 5000ft and upwards.

Agrees fairly well with *M. Lyallii*, but in some respects approaches *M. Monroi.* The flowers are creamy white, and the leaves markedly hispid.

SCROPHULARIACEAE.

Pygmaea ciliolata Hook. f.
Avalanche Peak, 4500ft.

LABIATAE.

Mentha Cunninghamii Bentham in D.C.
Road near Kennedy's, in very small quantities.

PLANTAGINACEAE.

Plantago Raoulii Decne.
Punch Bowl Flat and swamps behind railway settlement.

COMPOSITAE.

Lagenophora Barkeri T. Kirk.
Swamp in the settlement.

L. pumila (Forst. f.) Cheesem. var. *minima* T. Kirk.
Bealey River bed and above Rough Creek 4500ft.

Brachycome Thomsoni T. Kirk var. *polita* Cheesem.
Shade in the lower Mingha Valley, in forest.

Gnaphalium Mackayi (Buch.) Ckn.
Fell field 3000 to 4000ft.

Raoulia lutescens (T. Kirk) Beauv.
Halpins to settlement, river bed.

Cotula dioica Hook. f.
Bog in settlement.

C. dioica Hook. f. var. *crenatifolia* T. Kirk.
Swamp in bush at junction of Mingha and Bealey.

Olearia moschata Hook. f.

There are one or two specimens that would undoubtedly have been included by Cheeseman in this species, growing on the Bealey River bank above Punch Bowl Creek. Indeed, Cheeseman records it from Arthurs Pass with an exclamation mark, the specimens having

been collected by T. Kirk. Unfortunately, in the locality where it is seen, there are a number of apparently hybrid *Olearias*. *O. cymbifolia*, *O. ilicifolia*, *O. arborescens*, and *O. avicenniaefolia* also occur, and the status of *O. moschata* forms may be doubtful.

Species previously recorded, not seen by Laing and Oliver, now collected by Laing and Gourlay.

Agropyron aristatum (Petrie) Cheesem.
Shingle in creek bed, near Kennedy's
A well-developed form, with panicled spike.

Carex Berggreni Petrie.
By roadside, Lower Bealey.
This still leaves *Deschampsia Chapmani* not recently observed.

Corrections to Previous List (1929).

Lycopodium selago L should read *L. australinum* Herter.

Cystopteris fragilis should read *C. novae-zelandiae* J. B. Armstg.

Pittosporum tenuifolium should read *P. Colensoi* Hook. f.

A few specimens only have been seen, near the mouth of Halpins Creek, and these are exactly similar to others near the Otira township which have been identified by various botanists as *P. Colensoi*. What the true *P. Colensoi* is, we, of course, do not presume to say.

Rubus australis Forst should read *R. australis* Forst. var. *glaber* Hook f.

The plant is not uncommon in the lower Bealey.

Pseudopanax lineare (Hook. f) Laing and W. R. Olivêr, n. comb. should read *P. Lineare* (Hook. f.) C. Koch.

Hebe salicifolia (Forst) Pennell should read *H. salicifolia* (Forst.) Pennell var *communis* Ckn.

Hebe vernicosa (Hook. f.) Ckn and Allan should read *H. vernicosa* (Hook f) Ckn and Allan var. *Canterburiensis* (J. B. Armstrg) Ckn. and Allan.

We are following Dr Cockayne's advice in this direction, though we are not quite clear about the position. Cockayne (1927), p. 30,* states var. *Canterburiensis* " is the sole variety in the vicinity of Arthurs Pass and the adjacent mountains of the Western Botanical District. It is usually smaller and more prostrate than other varieties of the species " However, we have found Hebes of this species, particularly in the Mingha Valley, in rather varied forms, some of which approach to and may be hybrids with *H. buxifolia*. What the type of *H. vernicosa* is, we do not know.

Olearia nummularifolia should read *O. cymbifolia* (Hook. f.) Cheesem.

Helichrysum microphyllum (Hook. f.) Benth. and Hook. f. should read *Helichrysum selago* (Hook. f.) Benth. and Hook. f.

* Cockayne and Allan (*Trans. N.Z. Inst.*, Vol. 57). Taxonomic Status of New Zealand Species of Hebe.

Three forms of Pterostylis from creek near Gaya Cottage, Arthur's Pass.

Notes and Descriptions of New Zealand Lepidoptera.

By CHARLES E. CLARKE, F.E.S.

[*Read before the Auckland Institute on 16th November, 1932; received by Editor, 10th December 1932; issued separately, May, 1934.*]

NYMPHALIDAE.

Hypolimnas bolina nerina Fabr.

This handsome butterfly, usually considered rare in New Zealand, has been captured in various places and reported from others during the past two years.

Several specimens have been presented to Auckland Museum, their habitats having been Dargaville, Waiotira, Herne Bay, and Lake St. John.

NOCTUIDAE.

Ichneutica cana Howes.

This rare moth, known formerly from only one specimen taken many years ago by Mr G. Howes in the Garvie Mountains, has now again been captured in the Lake District. The second specimen was discovered at 3000ft on Ben Lomond, near Lake Wakatipu, in December Superficially the species appears close to *Aletia empyrea* Huds., but is a smaller insect.

GEOMETRIDAE

Chloroclystis tornospila Meyr.

In my paper "Lepidoptera of Auckland and the King Country," *Trans. N.Z. Inst.*, LII., 37, I mentioned capturing a fine unknown Chloroclystis at Waimarino. This I have now identified as the above apparently rare species, since described by Mr E. Meyrick.

Dasyuris octans Huds.

This species was first captured in 1923 by Mr S. Lindsay and myself at about 3500ft on Flat Top Mountain, south of Lake Mànapouri I again visited the locality in 1928 and took a further series of it. Apparently local, it was captured flying over an outcrop of lichen-covered rocks on a sunny slope surrounded by native grasses and herbs.

HYDRIOMENIDAE.

Xanthorhoe citroena n. sp. ♂ 32-36 mm. ♀ 28-30 mm.

Forewings moderate, with rounded hind margin; suffused with deep orange; two or three whitish arched fasciae near base, one or two median fasciae, more or less interrupted in middle in some specimens, attenuated in others, partly bordered with brownish which has tendencies to form several indistinct transverse wavy lines; beyond middle a whitish fascia, waved and angulated at about middle; a wavy subterminal line.

Cilia light orange slightly barred with brownish. Hindwings deep orange with lighter suffusion alternating with brownish.

This species is immediately recognisable by its deep orange colour though evidently allied to *X. clarata* Walk.

I captured several at the edge of the Franz Josef Glacier, Westland, in December, 1928, and I am indebted to the late Mr Alfred Philpott for isolating this species, which he had intended to describe. It is evidently local, no links with *clarata* having been discovered.

Holotype, allotype, and a paratype in collection Auckland Museum.

Hydriomena harmonica Clarke. *Trans. N.Z. Inst.*, LVI., 417.

I described this beautiful and interesting insect, of which an excellent illustration is given in Hudson's "Moths and Butterflies," p. XLVIII., 19, as a subspecies of *H. callichlora* Butl., but since it was discovered at Waitati in 1917 no affinity has been found connecting it with that species. I now consider it of specific rank, not a development of *callichlora*, but, on the contrary, a reversal to an ancestral form of that species.

The vivid blue and orange fasciae suggest an ancient tropical line of ancestry.

It is interesting to note that the specimen is an excellent example of cyanism. The dorsal surface of the species *callichlora* has evidently acquired, in the procession of its generations from a fairly archaic type, a most valuable evolutionary development in the arising of the characteristic protective "mossy-surfaced" green-pigmented expanse over body and wings; fusing and merging of fasciae of the two pigments that blend to produce this secondary green is well exemplified in the almost homogeneous effect produced.

Harmonica is a species most conspicuous to its enemies the birds, but *callichlora* exhibits protective resemblance in an extremely specialised manner.

Holotype in collection Auckland Museum.

PYRALIDIDAE.

Diptychophora planetopa Meyr.

This species, one of the rarest of the genus, I found occurring rather sparingly on the mountains at Arthur's Pass, above the Otira River, at about 3500ft. in January. I have never captured it elsewhere.

The type, however, was primarily taken in the Routeburn River Valley, Otago, by Mr G. V. Hudson.

Crambus malacellus Dup.

On my first two collecting tours to Whangarei and the North Auckland Peninsula (1921 and 1924), I did not meet with this introduced species.

It is now, however, rapidly becoming plentiful in the Auckland Province. I first captured it in company with Mr Arthur Richardson, at night, Whangarei township, in 1927. By the year 1931 it had become plentiful. This year, 1932, it is very abundant at Lake Takapuna, near Auckland.

Gauna aegalis Walk.

Aglossa cuprealis Hubn.

Almost similar remarks apply to these two species as to the foregoing.

The first specimens I had seen were captured about 1926 by Mr Arthur Richardson, at Papakura. By this year, 1932, both species had become remarkably plentiful at Lake Takapuna and Castor Bay, and at other localities near Auckland city. These insects are notable examples of the rapidity with which certain of the introduced fauna can become established in New Zealand.

TORTRICIDAE.

Gelophaula aridella n. sp. 15 mm.

Antennae dark-fuscous. Palpi fuscous. Head, thorax, and abdomen dark fuscous. Forewings sub-oblong, costa moderately arched, termen rather oblique, rounded at tornus; dark fuscous, obscurely darker along costa and greyish externally; cilia greyish fuscous. Hindwings fuscous; cilia grey-fuscous. Two specimens on Flat Top Mountain, Lake Manapouri, in January. This species is probably nearest *palliata* Philp, but distinct in several particulars, especially in size and in the almost unicolorous appearance of the hindwings. It is the smallest Gelophaula known to me.

Holotype in collection Auckland Museum.

Tortrix tigris Philp.

Ctenopseustis fraterna Philp.

These two usually rare species were not uncommon in Wayby Gorge in January. The latter insect was at first thought to be a variety of *C. obliquana* Walk., but after capturing a series, it was obvious, on subsequent examination, that the species is constant and distinct.

TINEIDAE.

Sitotroga cerealella Ol.

Another introduced species, of which I have only taken a single example in North Auckland; formerly reported from Levin by Mr G. V. Hudson. This insect in all probability will also become well established throughout New Zealand.

Tinea granella Linn.

This apparently unrecorded species I captured in Dunedin city. It is also an injurious introduction; an established pest in the granaries of Europe, America, and North Africa.

Gelechia calaspidea n. sp. 14 mm.

Head pale brownish-ochreous. Palpi whitish; antennae fuscous. Thorax fuscous; abdomen greyish towards extremity; legs fuscous mixed with whitish. Forewings with costa very slightly arched, apex slightly pointed, termen oblique; brownish fuscous, a darker distal dot, and dark suffusion on extremity of apex; cilia light fuscous. Hindwings and cilia light fuscous.

At 4000ft., Flat Top Mountain, Lake Manapouri, in January.

Holotype in Auckland Museum.

Perhaps nearest *G. contraria* Philp, but immediately seen to differ by the lack of the light bar along dorsum and other details, and to be distinguished from *schematica* by the absence of the grey streak along costa and the dark irroration, etc.

Izatha phaeoptila Meyr.

In my paper "Lepidoptera of Auckland," Trans. LII., 36, I included *Coridomorpha stella* Meyr. in error for this species, which I have captured at Hikurangi, Kauri Gully, Northcote, and Lake Takapuna. It is an uncommon insect.

Mallobathra memotuina n. sp. ♂ 12 mm. ♀ 14 mm.

Head and palpi purplish and fuscous brown. Antennae dark fuscous with admixture of ochreous; ciliations in ♂ 2.

Thorax and abdomen dark purplish brown; legs purplish brown mixed with ochreous and annulated on tibia and tarsi.

Forewings elongate; costa moderately arched, apex rather acutely rounded, termen strongly oblique; purplish fuscous with 5 to 6 ochreous white fasciae from costa. Basal one is at about $\frac{1}{6}$ outwardly oblique, second at $\frac{1}{3}$ inwardly oblique, the third at $\frac{1}{2}$ broken in centre of wing after waving outwardly, then inwardly to dorsum, the fourth at $\frac{2}{3}$ more straight to dorsum, but sometimes broken and spotted with purplish, fifth and sixth close together before apical patch, outwardly oblique; cilia dark fuscous.

Hindwings dark fuscous; cilia fuscous, apically pale.

Not close to any other species. Holotype and allotype in Auckland Museum. Anderson's Bay, Dunedin, on the face of the Vauxhall cliff, in November and early December, 1928 and 1929; both captured shortly after daybreak.

Mallobathra cataclysma n.sp. ♂ 9 mm.

Head and palpi grey ochreous. Thorax grey fuscous, abdomen fuscous. Antennae grey fuscous, ciliations 2. Forewings elongate, costa arched, apex acutely rounded, termen oblique; very pale ochreous with fuscous markings and irroration, the most distinct at about ½ on costa, others at ¾ broken and irrorated, distinct on dorsum; others across from near edge of termen. Cilia pale. Hindwings grey; cilia pale grey.

A much larger and more robust species than *M. metrosema* Meyr. and more pale in shade. Differs from *M. globulosa* Meyr. in its smaller size, more pale shade, shape of markings, and length of antennal ciliations. This is the most lightly-shaded *Mallobathra* known to me.

One only, discovered actively walking on the bark of Nothofagus: Harris Saddle, upper Routeburn River, in January.

Holotype in Auckland Museum collection.

Sabatinca abyssina n. sp. ♂ 12 mm.

Head and thorax aeneous. Antennae dark fuscous, base aeneous. Abdomen dark fuscous. Forewing ovate, rather blunted at apex; very pale aeneous with fasciae of dark purple; an irroration of purple dots on base to ⅓ of costa, where a wide outwardly oblique fascia of dark irrorated purple crosses to dorsum, another sub-parallel at beyond ½, and another also sub-parallel, more or less bifurcated, towards apex, some loose irroration between fascias, of purple dots. Cilia ochreous-aeneous. Hindwings dark purplish grey. Cilia pale ochreous-aeneous.

This is the largest species of *Sabatinca* known to me. It was taken on the rough, iceworn rocks at the north-eastern side of Franz Josef Glacier, Westland, in January.

Holotype in collection Auckland Museum.

Sabatinca lucilia Clarke.

Since my discovery of this strangely beautiful moth, the most archaic of the Micropterygidae, and, indeed, of all our Lepidoptera, as demonstrated by its venational reticulation (see Philpott's drawings, *Trans. N.Z. Inst.*, LIV, 161), no other collector seems to have met with the species.

I, however, have again captured it, in the Wayby Gorge, North Auckland Peninsula. In December, 1931, I discovered a colony of about 30 specimens in the shelter of an arching cliff, among moss

and fern-clad rocks. All were captured within a radius of about five feet, diligent search disclosing no more individuals in the neighbourhood.

Later, however, I found an isolated one also at the Waipu Caves, in late December. The type I netted, in 1915, at the Waitomo Caves. The occurrence of this primitive Lepidopter is noteworthy, as it is most interesting from an evolutionary standpoint, being a close link with the Trichopterygidae, and with that order exhibits affinities with the extinct *Aristopsyche* and *Archipanorpa* of the Paratrichoptera, as demonstrated by Dr Tillyard.

An Iodine Survey of New Zealand Live-stock.

PART II.

THE SHEEP OF THE WAIRARAPA DISTRICT.

By P. H. SYKES.

[*Received by Editor, 23rd May, 1933; issued separately, May, 1934.*]

SYMPTOMS suggesting acute iodine deficiency in the sheep of the Wanaka district (South Island) have been reported and described by Hopkirk, Dayus, Simpson, and Grimmett (1930). There the loss of lambs was serious, and the cure, by means of iodised licks, complete and impressive. A research was therefore inaugurated by the Department of Agriculture to find whether this deficiency was present in milder form in other parts of the country, and if so, the conditions under which it occurred and the best methods of treatment. An account of the investigation of Otago and Southland has already been published as Part I of this series by E. M. Mason (1933). The following is an account of the progress that has been made in the North Island.

The presence or absence of iodine deficiency has been ascertained from the analysis of the thyroid glands, and the results have been correlated with data referring to the conditions under which the sheep were reared. The glands were obtained from the freezing works of the district, through co-operation with the Government Veterinarian, who also supplied details of age, sex, supplementary feeding, type of soil, and morphology of the district. Each sample consisted of the thyroids of about eight animals chosen as fair representatives of the flock.

Analysis: The glands were dissected free from fatty tissue, weighed, estimated for moisture, and analysed for total iodine by the modified method of Fellenberg (Leitch and Henderson, 1926-30) adapted slightly for thyroids, but the same in all details as used by E. M. Mason (1933).

An outline of the procedure is as follows:—

The dried gland is digested in potassium hydroxide (Merck extra pure) and an aliquot of the solution evaporated to dryness in a nickel crucible. The residue is ashed at a low temperature, cooled, moistened with distilled water, dried, and ashed again, the process being repeated three or four times till the ash is greyish-white. It is then moistened and evaporated till a skin appears on the surface. It is extracted four times, each with 3 cc. of alcohol (distilled from sodium carbonate) and filtered into a small nickel crucible, evaporated

to dryness, and drawn over a burner for five seconds to destroy traces of organic matter. The residue is dissolved in distilled water and an aliquot taken. This solution, containing the iodine in the form of potassium iodide, is made just acid, and the iodide oxidised to iodate with freshly prepared bromine water. The iodine is then liberated with excess potassium iodide solution (freshly prepared), starch is added, and the blue colouration is removed with N/500 thiosulphate, using a micro burette, and arranging quantities to obtain a titre of about 1 cc. The end point is determined by making a series of titrations varying by 0.02 cc. and accepting the figure between that value at which the colouration just reappears on standing, and the nearest one at which it disappears.

The condition of the thyroid gland was studied in relation to the factors of (1) age, (2) sex, (3) soil type, (4) iodine feeding; the first two being constitutional, the last two environmental.

(1) *The condition of the thyroid gland in relation to the age of the sheep:*

Samples from animals, varying in age from three months to six years, showed that age considerably affected the glands. The following are the results:—

Description	Fresh weight of gland in grams.	% Moisture.	% Iodine on fresh weight.
Sheep (1½-6 years old). Average of 5 samples ..	3.95	70.0	0.141
Lambs (3-6 months old). Average of 86 samples ..	2.25	73.3	0.073

The number of sheep thyroids was not sufficient to allow the matter to be treated statistically, but from the figures available it appears that both the weight of the gland and the per cent. iodine are considerably greater in the older sheep. This result is, at least, sufficiently definite to show that where figures are being studied for any other factor, sheep results must be separated from the results of younger animals, and, in the rest of the work only lambs' thyroids are considered.

(2) *The condition of the thyroid gland in relation to the sex of the*

The effect of sex was also investigated, and it was found that the glands of male lambs did not differ in any way from those of

female lambs. The following are the results of 43 samples of glands from male lambs with the corresponding samples from female lambs:

Description.	Fresh weight of gland in grams.	% Moisture	% Iodine on fresh weight.
Male lambs.			
Average of 43 samples		73 4	0 072
Female lambs.			
Average of 43 samples		73.2	0 073

These results are represented graphically in the following cumulative distribution diagrams, which are a modification of the ogive (Fisher 1927) in which the scale is adapted so that a normal distribution results in a straight line. A complete explanation of this type of graph is given by Dufton (1930) The points are obtained by taking the percentage of the samples as ordinates, which lie on or below the different values shown as mantissae The more nearly normal the distribution is, the more nearly straight will be the curve drawn through these points, the more upright the curve, the closer the limits of variation, and if on one diagram two or more curves are drawn, then the nearer they lie, the more nearly identical are the results they represent If they lie distinct from one another there is a significant difference in the results

The value on the curve, corresponding to the 50 per cent. mark is the median, half the samples having more and half less than this value. If the distribution is normal, then this value will also be the mean or average. It will be seen from the table above and in Diag. I-III that in this case the mean and the median agree very closely.

For the results embodied in this paper the chief advantage of this type of presentation over the more familiar histogram lies in the greater facility with which several sets of figures can be represented on one diagram.

No marked difference can be detected in per cent. iodine, wet weight, or per cent. moisture, either from the figures above or from the distribution diagrams. It was concluded, therefore, that there was no variation in lambs' thyroids in relation to sex. Fenger (1913) studied cattle and reported finding the per cent. iodine in the female slightly higher than in the male. Seventeen male thyroids had an average of 0.21 per cent. on the dry gland; twenty-three female thyroids had an average of 0.25 per cent. McCarrison and Madhava (1932) found that in rats the weights of the male thyroid glands were greater than the weights of female glands, but considered this to be due to the increased body weight of the male, and that for the same body weight there is no significant difference in weight between the glands of male and female. In the present case it is animals of approximately the same body weight which are being studied, because the lambs are those selected by fat stock buyers for killing purposes. The results obtained showing no significant difference in weight between male and female glands is therefore in agreement

with that of McCarrison and Madhava. For the remainder of the work the plan was adopted of combining the data obtained from both sexes.

(3) *The condition of the thyroid gland in relation to soil type:*

The Wairarapa district is an area approximately 100 miles long and 50 miles broad. It is bounded on the west and the south-east by greywacke mountains. To the east the hills are mainly younger marine sediments—papa and mudstone (Miocene and Cretaceous), with strips of Pliocene limestone. The broad central area, comprising the river bed of the Ruamahunga River and its tributaries, consists of alluvial plains of greywacke gravel, subject to flooding, whilst on the east coast, associated with the Wareama River, there is a smaller alluvial plain. The rainfall is 40-60 inches, with 120-180 rain days.

For the purposes of this study, the district has been divided into four: (a) limestone, (b) greywacke, (c) papa, (d) alluvium, all of which, with the possible exception of the papa, are fairly pure representatives of their type. Analyses of the glands obtained from these types are given below in four groups with an extra division for swamps. The number of lobes, of which there are two to each gland, is given rather than the number of glands, as some mutilated lobes were rejected, leaving an odd number in some of the samples.

TABLE I.

LIMESTONE (21 samples)

Sample No.	Fresh weight, grams	Dry weight, grams	% Iodine fresh	% Iodine, dry	Total Iodine, grams	% Moisture	No. of lobes	Locality
7	1.693	0.475	0.134	0.467	0.00227	72.0	18	Te Ore Ore
8	1.530	0.417	0.117	0.429	0.00179	72.7	20	"
9	1.991	0.592	0.106	0.357	0.00211	70.2	20	Pahiatua
10	1.968	0.489	0.093	0.376	0.00184	75.1	16	"
11	1.999	0.540	0.092	0.340	0.00183	73.0	18	Gladstone
14	1.953	0.584	0.097	0.324	0.00189	70.1	28	Rangitumu
23	1.641	0.495	0.033	0.109	0.00054	69.8	18	Longbush
27	1.622	0.511	0.131	0.416	0.00213	68.5	12	"
29	2.327	0.626	0.091	0.338	0.00211	73.1	16	Konini
30	2.160	0.618	0.092	0.321	0.00198	71.4	16	"
32	1.374	0.418	0.109	0.359	0.00150	69.6	20	Pahiatua
34	1.990	0.588	0.091	0.309	0.00182	70.5	24	"
52	1.767	0.496	0.125	0.445	0.00221	71.9	18	Mauriceville
53	1.866	0.504	0.120	0.446	0.00225	73.0	16	"
56	2.452	0.702	0.097	0.337	0.00237	71.4	20	Gladstone
57	1.746	0.461	0.097	0.367	0.00169	73.6	14	"
58	1.433	0.374	0.077	0.297	0.00111	74.0	16	"
59	3.355	0.932	0.064	0.229	0.00214	72.5	20	Longbush
60	1.505	0.398	0.074	0.279	0.00111	73.6	16	Gladstone
74	1.809	0.478	0.105	0.398	0.00190	73.6	12	Pahiatua
78	2.010	0.560	0.109	0.393	0.00220	72.2	20	"
Aver.:	1.91	0.537	0.094	0.349	0.00185	72.0	18	

TABLE II.

GREYWACKE (13 samples).

Sample No.	Fresh weight, grams	Dry weight, grams	% Iodine, fresh.	% Iodine, dry.	Total Iodine, grams	% Moisture.	No of lobes	Locality.
3	1.640	0.480	0.082	0.280	0.00134	70.7	14	Martinborough
4	1.814	0.518	0.083	0.292	0.00151	71.4	12	,,
21	1.840	0.501	0.089	0.327	0.00164	72.8	6	Mt. Bruce
25	2.074	0.589	0.091	0.323	0.00190	71.6	24	,,
33	1.960	0.576	0.125	0.427	0.00246	70.6	16	Martinborough
35	1.832	0.538	0.108	0.367	0.00197	70.6	18	,,
63	2.036	0.520	0.089	0.350	0.00182	74.5	10	Carrington
65	2.117	0.540	0.077	0.303	0.00164	74.5	8	,,
70	2.455	0.633	0.056	0.215	0.00136	74.2	18	,,
75	2.227	0.579	0.068	0.261	0.00151	74.0	16	Upper Hutt
83	1.984	0.538	0.073	0.270	0.00145	72.9	14	,,
85	2.526	0.562	0.056	0.253	0.00142	77.8	14	Stronvar
87	2.095	0.420	0.062	0.311	0.00130	80.0	6	,,
Aver.:	2.05	0.540	0.082	0.306	0.00164	73.5	14	

TABLE III.

PAPA (21 samples).

Sample No.	Fresh weight, grams.	Dry weight, grams.	% Iodine, fresh	% Iodine, dry	Total Iodine, grams	% Moisture	No. of lobes	Locality
5	1.663	0.475	0.126	0.442	0.00210	71.4	16	Martinborough
6	2.035	0.596	0.147	0.501	0.00299	70.7	14	,,
16	2.537	0.746	0.118	0.401	0.00299	70.6	20	Pongaroa
17	2.013	0.590	0.035	0.121	0.00071	70.7	19	,,
22	2.066	0.560	0.113	0.416	0.00233	72.9	18	Bideford
28	2.140	0.602	0.074	0.262	0.00157	71.8	20	Pahiatua
31	2.035	0.545	0.075	0.279	0.00152	73.3	20	Tinui
36	2.171	0.613	0.077	0.266	0.00163	71.8	20	,,
37	1.874	0.532	0.078	0.274	0.00146	71.6	18	Pahiatua
38	2.829	0.710	0.044	0.173	0.00123	74.9	22	Bideford
39	2.158	0.552	0.050	0.195	0.00108	74.4	18	Martinborough
42	2.522	0.643	0.053	0.209	0.00134	74.5	20	,,
43	2.959	0.730	0.036	0.145	0.00106	75.4	16	Bideford
69	2.113	0.560	0.070	0.264	0.00148	73.5	14	Pongaroa
72	2.374	0.595	0.071	0.284	0.00169	74.9	12	,,
100	1.795	0.472	0.081	0.307	0.00145	73.7	14	Wangaehu
101	1.976	0.522	0.101	0.383	0.00200	73.6	11	,,
102	2.355	0.541	0.037	0.163	0.00088	77.0	12	Martinborough
103	2.471	0.629	0.040	0.158	0.00099	74.5	20	,,
104	3.027	0.838	0.049	0.177	0.00148	72.3	22	Pahiatua
105	2.602	0.706	0.041	0.189	0.00133	73.3	20	,,
Aver.:	2.27	0.608	0.072	0.267	0.00158	73.2	17	

TABLE IV.

ALLUVIUM (32 samples).

Sample No.	Fresh weight, grams.	Dry weight, grams	% Iodine fresh	% Iodine dry	Total Iodine, grams	% Moisture.	No of lobes.	Locality.
40	2.132	0.572	0.061	0.228	0.00130	73.2	25	Kaiwaiwai
41	2.509	0.682	0.064	0.236	0.00161	72.8	16	"
46	2.728	0.729	0.040	0.151	0.00110	73.3	10	Pigeon Bush
47	2.705	0.653	0.023	0.097	0.00063	79.6	12	"
48	2.125	0.556	0.060	0.228	0.00127	73.9	18	Featherston
49	2.132	0.564	0.054	0.204	0.00115	73.6	22	"
51	2.659	0.678	0.044	0.174	0.00118	74.5	24	Kahutara
55	3.703	0.843	0.022	0.095	0.00080	77.2	18	Pirinoa
64	2.961	0.785	0.035	0.131	0.00103	73.5	16	East Taratahi
67	2.776	0.706	0.037	0.147	0.00104	74.6	22	Homewood
68	2.751	0.810	0.046	0.157	0.00127	70.5	18	"
71	2.751	0.717	0.045	0.174	0.00125	74.0	18	Opaki
73	3.401	0.911	0.037	0.139	0.00127	73.2	24	"
76	2.904	0.714	0.044	0.178	0.00127	75.4	16	Upper Plain
77	2.713	0.707	0.060	0.231	0.00163	73.9	14	Pigeon Bush
79	1.954	0.508	0.077	0.297	0.00151	74.0	14	Martinborough
80	2.349	0.643	0.086	0.313	0.00201	72.6	18	Pigeon Bush
81	2.148	0.582	0.076	0.279	0.00163	72.9	16	Martinborough
82	2.088	0.522	0.051	0.203	0.00106	75.0	20	Upper Plain
84	2.525	0.671	0.080	0.302	0.00203	73.4	24	Opaki
86	2.575	0.659	0.050	0.196	0.00126	74.4	18	Langdale
88	2.815	0.703	0.049	0.198	0.00139	75.1	14	"
89	2.623	0.691	0.055	0.208	0.00144	73.7	20	Opaki
90	2.985	0.739	0.033	0.134	0.00099	75.2	18	Pirinoa
91	2.250	0.569	0.053	0.209	0.00119	74.7	16	Martinborough
92	3.112	0.757	0.032	0.130	0.00099	75.7	18	Pirinoa
93	2.547	0.572	0.027	0.120	0.00069	77.6	16	"
94	3.117	0.727	0.017	0.073	0.00053	76.7	18	"
95	1.893	0.458	0.049	0.205	0.00094	75.8	12	Martinborough
98	2.040	0.498	0.047	0.191	0.00095	75.7	12	Manaia
99	2.400	0.617	0.034	0.130	0.00080	74.2	20	"
109	3.468	0.849	0.023	0.093	0.00079	75.5	24	Pirinoa
Aver.:	2.62	0.668	0.047	0.183	0.00117	74.5	18	

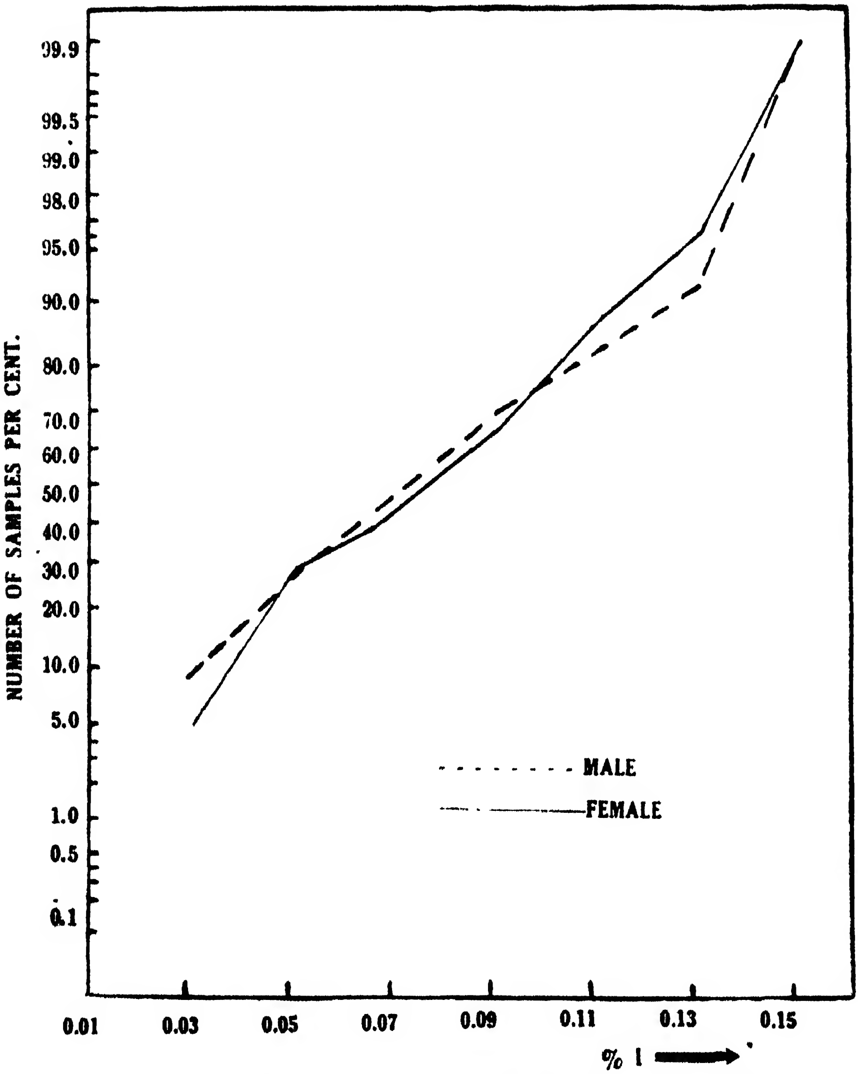
TABLE V.

SWAMP (4 samples).

	eight	Dry w grams.	Iodin h.	% I dry.				Locality.
44	1.799	0.528	0.111	0.414	0.00219	70.6	18	Kahutara
45	2.021	0.599	0.145	0.489	0.00293	70.3	14	"
96	1.787	0.480	0.102	0.380	0.00182	73.3	16	Opaki
97	1.817	0.497	0.111	0.407	0.00202	72.7	14	"
Aver :	1.856	0.526	0.117	0.422	0.00224	71.7	16	

DIAGRAM I.

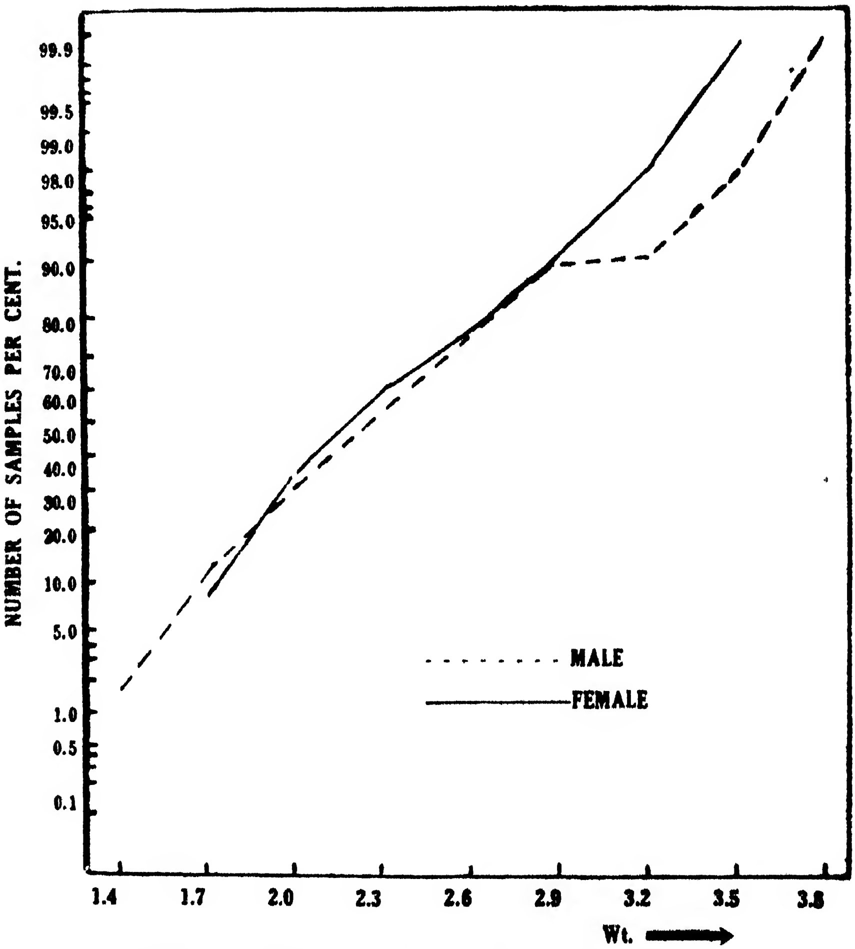
% IODINE



Cumulative distribution diagram of the % iodine in glands of male and female lambs.

DIAGRAM II.

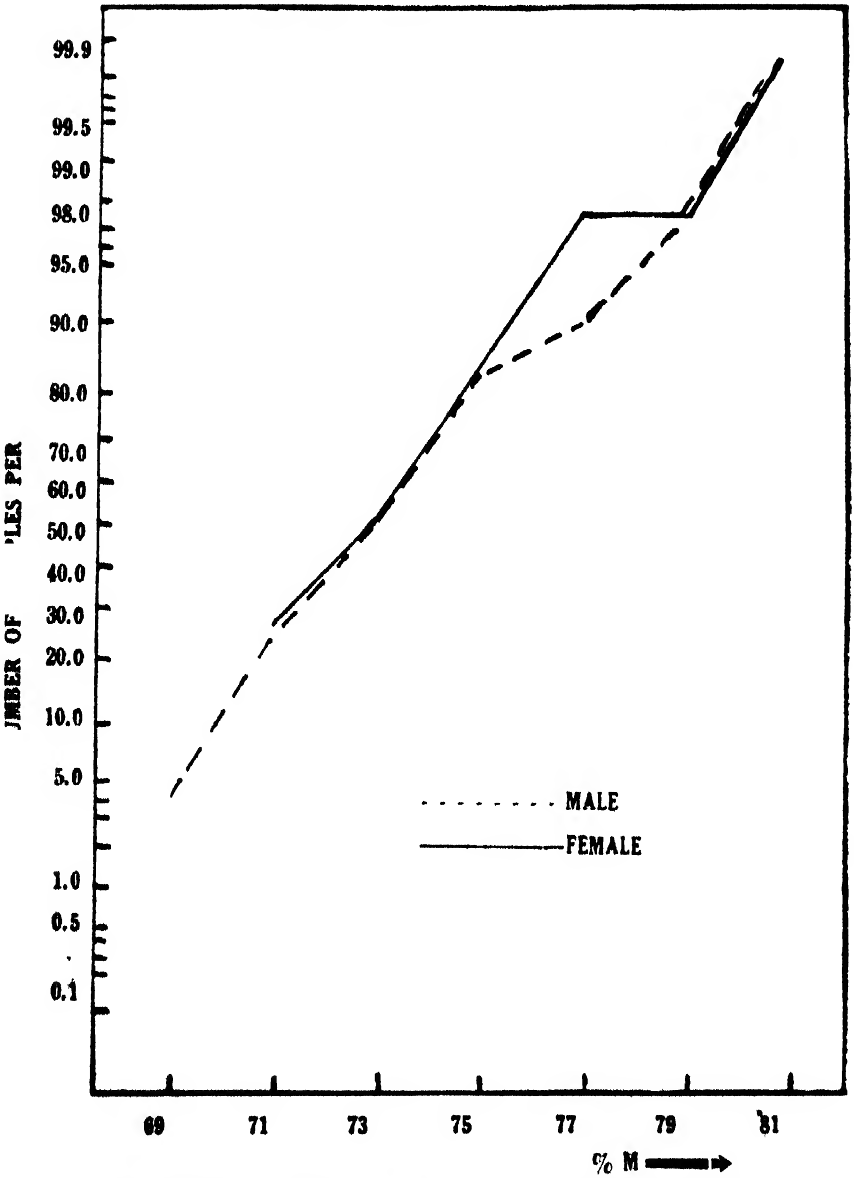
FRESH WEIGHT (Grams)



Cumulative distribution diagram of the weight of glands in male and female lambs.

DIAGRAM III.

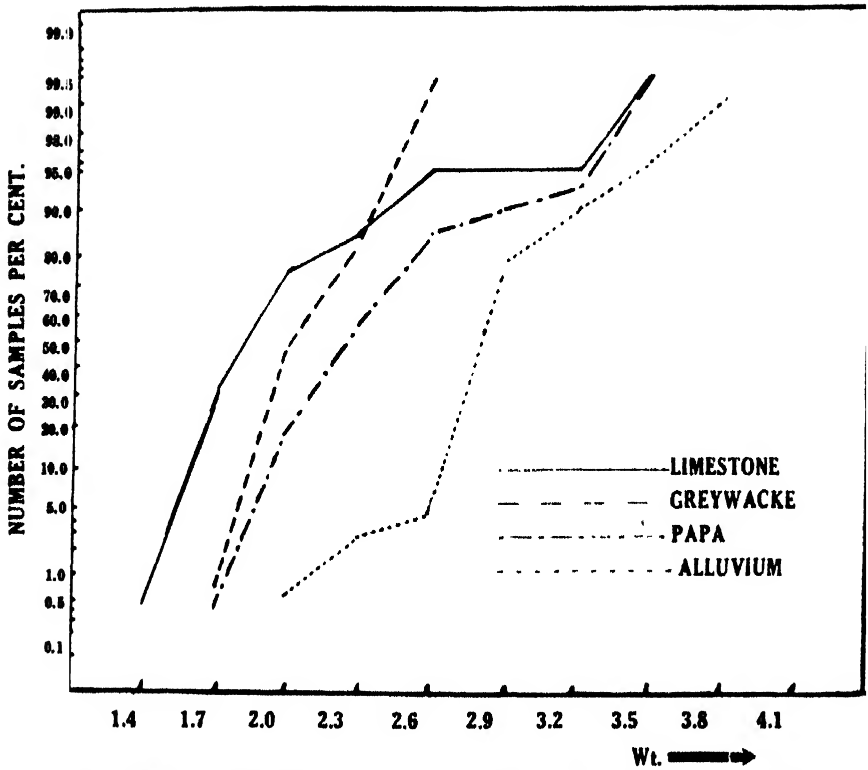
% MOISTURE



Cumulative distribution diagram of % moisture in glands of male and female lambs.

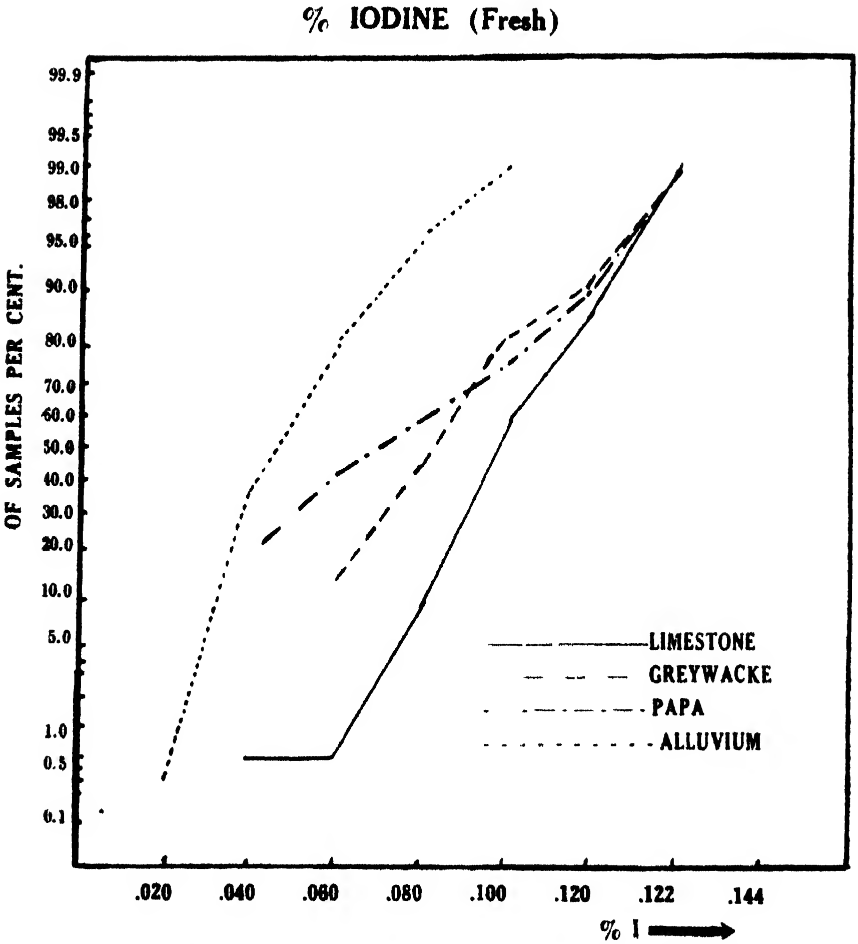
DIAGRAM IV.

FRESH WEIGHT (Grams)



Cumulative distribution diagram showing relation of fresh weight of glands to soil types.

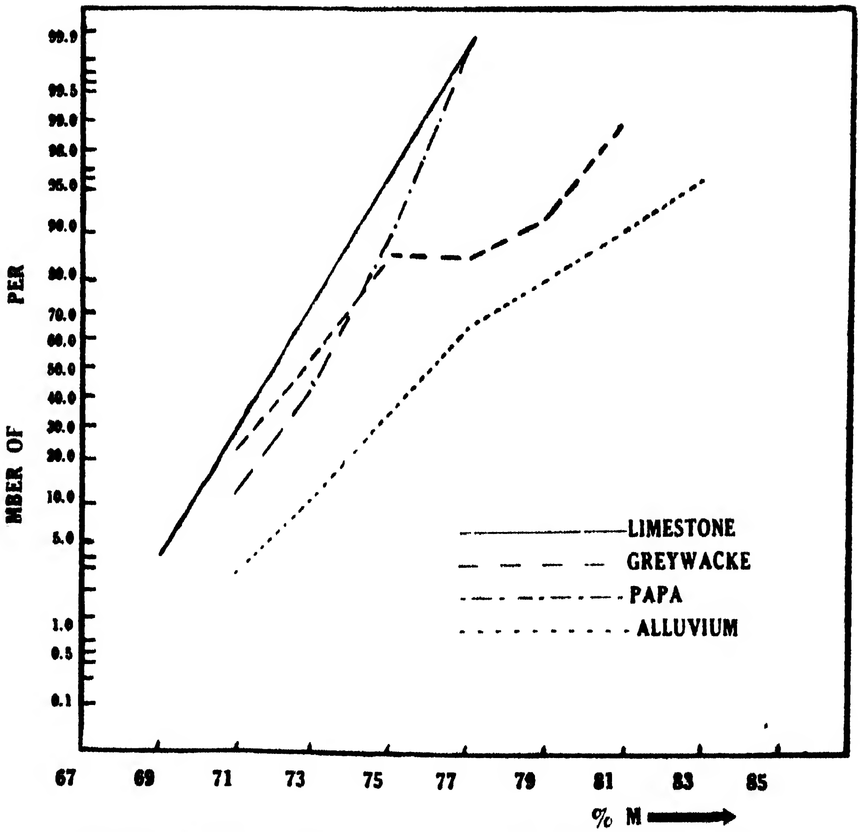
DIAGRAM V.



Cumulative distribution diagram showing relation of % iodine of glands to soil types.

DIAGRAM VI.

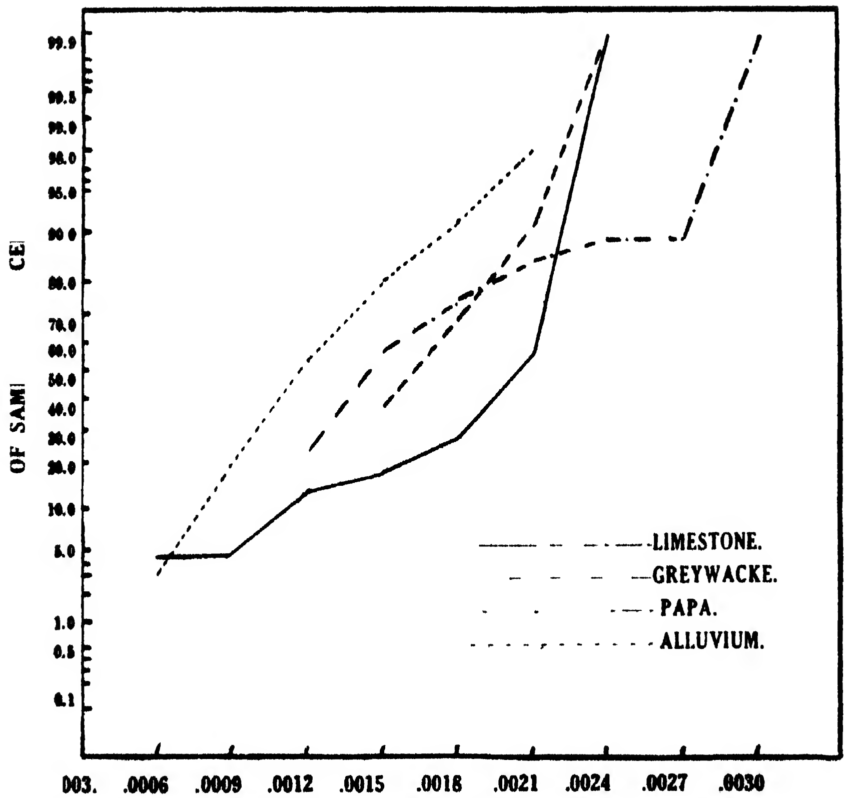
% MOISTURE



Cumulative distribution diagram showing relation of % moisture to soil types.

DIAGRAM VII.

TOTAL IODINE (Grams)



Cumulative distribution diagram showing relation of total iodine in glands to soil types.

(a) *Limestone:*

Many instances of goitre endemic on limestone areas are cited by Hercus, Benson, and Carter (1925) in their study of the relationship between goitre and geological type. In England, Lebour (1881) concluded that goitre was absent on Jurassic limestone, but was endemic on the older Carboniferous limestone. McCarrison showed that goitre was associated with limestone areas in Northern India. Clark and Pierce (1914) found goitre endemic on Silurian limestone in the Virginias. In Switzerland, however, the lowest incidence of goitre is associated with marine Mesozoic rocks, chiefly limestone, marl, and claystone.

This great disparity between the relationship of goitre to limestone is not surprising, for there are, besides iodine deficiency, other goitrogenic agents which may or may not be operating in the localities studied. Again, the iodine content of different limestones must vary according to factors such as the amount of organic matter originally deposited, to the time and severity of leaching, to the presence or absence of clays and other colloids which would tend to prevent the leaching, to vegetable and animal life, and to the cropping. Further, lime itself tends to cause thyroid enlargement, especially in conjunction with vitamin and iodine deficiency (McCarrison and Madhava, 1932). No conclusions can be made, therefore, concerning the goitrogenic effect of limestone formations generally, although conditions for particular deposits appear to be constant.

The formation at present being studied is a comparatively recent marine deposit, rich in organic remains. From the preceding figures and diagrams it is seen that the glands from this area have the greatest percentage and total iodine, and least weight and percentage moisture of any of the groups, excluding the swamp samples. There is only one case of a sample of average weight greater than three grams, and only one of low iodine content. The limestone areas of this district may be said, therefore, to be free from goitre.

(b) *Greywacke:*

Greywacke deposits, in their relation to goitre incidence, have not been as fully reported on as limestone. In the present case the glands from the greywacke areas rank next to those from the limestone in point of iodine content and freedom from enlargement; no suggestion of iodine deficiency was obtained from this area.

(c) *Papa:*

Concerning formations of this nature, Hercus, Benson, and Carter (1925) quote conflicting reports. Lebour (1881) considered that goitre was absent from Jurassic claystone and rare on Cretaceous claystone. McCarrison found Cretaceous and Post Tertiary deposits comparatively free from goitre. Clark and Pierce (1914) describe the presence of claystones in the non-goitrous areas of Virginia.

It may be that the nature of the deposit varies in the preceding cases; it certainly does in the case of the Wairarapa deposits. Some parts are dark grey Cretaceous mudstone and some are light-coloured

miocene papa; some parts are fossiliferous and others are not. Attempts at further dividing this type were not successful, so more samples are being obtained which may make the matter clearer.

Although lacking uniformity, samples from this area, when compared with those from the limestone and greywacke areas, show a definitely lower iodine content and an increased weight. There is, however, no instance of gross enlargement or acute iodine deficiency in any of these samples.

(d) *Alluvium:*

High incidence of goitre associated with alluvial soils in New Zealand has been demonstrated by both Hercus, Benson, and Carter (1925) and Shore and Andrew (1929). The same phenomenon has been observed in Switzerland and in North America, in the region of the St. Lawrence and the Great Lakes (Orr and Leitch, 1929).

Although the application of fertilizers, which have been shown by Hercus and others (1931) to increase the iodine content of the pastures, has been more extensive on the alluvial plains than on limestone, greywacke, and papa hills, yet the thyroid glands from the plains are low in iodine and high in weight. In some cases the percentage iodine is less than 0.03 (fresh), the level below which normal functioning of the gland is considered by Marine and Lenhart (1901) to be impossible.

The samples with the smallest iodine content and the greatest weight come from the lower part of the valley near the mouth of the Ruamahunga River. Shore and Andrew (1929) showed that the iodine content of the soil exhibited a marked decrease on proceeding down the valley towards the sea. Apparently in both these river basins, which are subject to flooding, the soil has been more thoroughly leached of iodine in the lower part of the valley.

The samples in the alluvial group show a lower iodine content and a higher weight and moisture percentage than those in any other group. Not even the glands of lowest iodine content, however, show any gross enlargement.

(e) *Swamp:*

In swamps there is a large accumulation of organic matter, and this type of soil has been shown by Shore and Andrew (1929) to be particularly high in iodine. The glands from swampy areas are therefore considered separately from those of the alluvial plains on which these swamps occur. The glands show a higher iodine content and a lower weight than those of any of the preceding groups.

Relationships among the Changes in the Gland:

Taking the average figures of the groups considered, it is seen that a decrease in the total and relative amounts of iodine in the gland is accompanied by an increase in the fresh weight, the dry weight, and the percentage moisture.

TABLE VI.

	Fresh weight, grams	Dry weight, grams	% Iodine, fresh	% Iodine, dry.	Total Iodine, grams.	% Moisture
Swamp	1.86	0.526	0.117	0.422	0.00224	71.7
Limestone	1.91	0.537	0.094	0.349	0.00185	72.0
Greywacke	2.05	0.540	0.082	0.306	0.00164	73.5
Papa	2.27	0.608	0.072	0.267	0.00158	73.2
Alluvium	2.62	0.668	0.047	0.183	0.00117	74.5

(4) *The condition of the thyroid gland in relation to iodine feeding:*

The Wairarapa Training Farm, because of its position on the alluvial plains, was chosen for an experiment to find what changes in the gland and possible benefits to the animal would result from feeding iodised licks One batch (No. 1) received no lick, one (No. 2) received lick containing 2 oz. potassium iodide per ton of common salt, one (No. 3) received lick containing 60 oz. potassium iodide per ton. The lick was fed at the rate of 8 oz. per animal per month, from the middle of October till the middle of December, when the animals were killed.

The averaged results are given below:—

TABLE VII.

Batch No	Wet weight, grams	Dry weight, grams.	Body weight, lbs	r.*	% Iodine, fresh.	% Iodine, dry	Total Iodine, grams	% Moisture.	No of lobes.
1	1.76	0.478	36.4	10.65	0.051	0.189	0.00092	72.2	16
2	1.70	0.465	35.0	10.70	0.060	0.210	0.00107	73.1	22
3	1.80	0.558	35.2	11.26	0.105	0.351	0.00197	70.2	4

* "r" denotes $\dfrac{\text{thyroid weight} \times 10{,}000}{\text{body weight in grams}}$

This property is manured rather more heavily than most, and the control glands are, unfortunately for the experiment, not particularly poor in iodine, nor do they show any tendency to enlargement. The effects of iodine feeding are not as marked, therefore, as could have been expected had the controls shown the tendency to low iodine content and enlarged gland, which characterises most of the glands taken from the plains.

No regular change has occurred in the weight or the moisture percentage of the glands, nor in the body weights of the animals, and although the ratio (r) of the thyroid weight to the body weight shows a regular increase, it is small, and its significance doubtful. The absolute and relative amounts of iodine in the gland have increased in accordance with the dose administered.

Summary:

(1) Analyses have been made of a large number of thyroid glands of lambs and sheep from the Wairarapa district in the North Island of New Zealand.

(2) The iodine estimations have been made by the method of Leitch and Henderson (1926)

(3) The glands of older sheep have been found to differ materially from those of lambs, and have been omitted from subsequent considerations.

(4) No difference could be detected between the glands of male and female lambs.

(5) The Wairarapa district has been considered from the point of view of the four main geological types there—limestone, greywacke, papa, and alluvium.

(6) The average iodine content of the thyroid glands from these types was found to be: —

	% Iodine on fresh weight
Limestone	0.94
Greywacke	0.82
Papa	0.72
Alluvium	0.47

(7) A decrease in the relative and absolute amounts of iodine in the gland is accompanied by an increase in the fresh weight, the dry weight, and the percentage moisture.

(8) In no case was there an occurrence of gross enlargement of the gland.

(9) Feeding lambs with iodised licks for two months before killing had the effect of increasing the iodine content of the thyroid glands, but no other changes or benefits were observed.

(10) The Wairarapa district is not an area of serious iodine deficiency.

The author wishes to record his indebtedness to Mr B. C. Aston, Chief Chemist, Department of Agriculture, for help and criticism; also to Mr W. C. Barry, District Superintendent, and Mr T. H. Hankin, Veterinarian, who arranged the sending of samples.

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F. B. SHORLAND, M.Sc.,

Chemistry Section, Department of Agriculture, Wellington.

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INTRODUCTION.

IN view of the fact that aluminium is the most abundant and widely distributed metallic element of the earth's crust, it is not surprising that it should prove a frequent, if not a universal, constituent of plant and animal tissues. Recent investigations, however, would seem to show that many of the earlier determinations of aluminium in biological materials are too high, much of the aluminium reported having come either from contamination by soil dust or from the traces of aluminium invariably present in the reagents employed.

While it is by no means certain that aluminium is essential either for plant growth or animal nutrition, the estimation of this element is of some importance in connection with the problem of soil contamination—a factor which frequently interferes with the determination of the true content in the pasture of certain trace constituents such as iron, manganese, and iodine. These elements usually occur to a much greater extent in soils than in pastures so that even traces of contaminating material may add very considerably to the amounts reported in the analysis of the mineral content. As many of these trace elements play an important part in animal nutrition, it is most desirable to determine the amounts of these elements actually elaborated by the plant tissues where they are probably present in a more digestible form than in the soil.

Although the greatest care may be exercised in obtaining clean pasture samples, experience has shown that the contamination factor can seldom be disregarded in the interpretation of the ash analysis. Indeed, in certain districts of New Zealand, as, for example, Morton Mains, Southland, the soil contamination of even carefully picked samples is so great as to mask any abnormalities in the true mineral content of the trace elements of the pasture.

For some years past Aston (1928)[2] has used the estimation of alumina as a significant aid in determining the degree of contamination by soil or fine atmospheric dust which the pasture sample has undergone. The principle involved depends on the fact that almost invariably the higher plants (to which grasses and clovers belong) absorb only traces of aluminium Jost (1907)[7], and hence, if more than traces of this element be found in the pasture sample, this must be attributed to soil or dust contamination.

Before alumina can be used as a quantitative index of contamination it is thus first necessary to determine the limits of the aluminium content of clean grasses and clovers. The excess

aluminium may then be attributed to the adhering material, which might be assumed to have the same mineral content as the finer particles of the soil on which the pasture grows. If the amount and composition of the contaminating material be thus ascertainable, the mineral content actually present in the plant tissues could be found on subtracting this from the mineral content of the contaminated pasture. It is quite possible, however, that the pasture contamination, often consisting largely of atmospheric dust, differs considerably in chemical composition from the soil beneath, and hence wherever practicable the best solution of the problem appears to be the removal of the contaminating material by careful cleaning prior to analysis

The present investigation was undertaken to obtain further information on some of the problems outlined above, and in particular to establish a satisfactory means of discriminating between the natural pasture minerals and those contributed by the adhering soil. Accordingly, a study was made of the limits of the alumina content of clean pastures and of the relationship of the alumina content to the soil contamination To facilitate the investigation the gravimetric methods ordinarily employed for the estimation of aluminium were replaced by a convenient colorimetric procedure described below

Aluminium in Plants.

During the past fifty years numerous investigators have made quantitative estimations of aluminium in plants. The wide variations in the results obtained, however, would seem to suggest that many of the samples analysed were contaminated.

According to the recent work of Bertrand and Levy (1931)[8] aluminium was found in all the phanerogams examined in amounts varying from one-tenth of a milligram to several hundred milligrams per kilogram of dry material. Winter and Bird (1929)[21] from the analysis of a number of plants and plant materials obtained results of a similar order. Since aluminium was still found to be present in those samples in which the outer skin had been removed, these investigators came to the conclusion that this element is probably a natural constituent of plant and animal tissues.

Generally speaking, the results of earlier investigators indicate that while aluminium occurs throughout all parts of the same plant, it is concentrated chiefly in the roots and is found only in minute quantities in the leaves.[5, 15] This, however, is not confirmed by the later work of Bertrand and Levy (1931)[8], who found that although edible roots appear to contain far less aluminium than wild roots, the greatest proportion of this element is contained in the leaves and appears to be related to the chlorophyll.[4] The inner etiolated leaves of the cabbage, for example, were found to contain only 8 milligrams whereas the outside leaves contained 232 milligrams of aluminium per kilogram of dry material.

The great majority of plants contain only traces of aluminium in unknown combination. In some samples of Lycopodium, however, as much as one-third of the ash is alumina which can be

extracted from the plant in combination with an organic acid.[17] Smith[19] reported abnormal quantities of alumina in the ash of *Orites excelsa* R. Br. (Proteaceae), where the aluminium appears to be necessary for growth, any excess being deposited in the cavities and natural fissures of the wood as basic aluminium succinate. In general, whereas xerophytes absorb only traces of aluminium, the hygrophytes are noted for their relatively high aluminium content, especially in the root.[20]

THE PHYSIOLOGICAL ACTION OF ALUMINIUM ON PLANTS.

According to Stoklasa[18] aluminium in very dilute concentrations exerts a favourable influence on seed germination while larger concentrations are toxic. Aluminium in certain suitable concentrations will apparently reduce the toxic effect of excess manganese. With regard to plant growth, the same observer has shown that aluminium is less toxic than iron, and in suitably low concentrations has the effect of reducing the toxicity of excess of either iron or manganese.

In contrast to the detoxicating and stimulating action of very low concentrations of aluminium salts, in recent years a considerable amount of discussion has taken place with regard to the toxicity of soluble aluminium salts present in appreciable amounts in certain acid soils. Line (1926)[10] contended that "the toxic aluminium theory" was untenable—the relatively poor growth of plants in soils or nutrient solutions to which aluminium salts have been added (as compared with the control plants) being entirely due to the progressive hydrolysis of the aluminium salts producing increased acidity and a depletion of the phosphate supply owing to the precipitation of aluminium phosphate. Recent work, however, has shown this contention to be groundless. Spencer[6], for example, found that the toxicity of aluminium salts to *Rhododendron ponticum* L. seedlings in sand cultures actually decreased with increasing acidity of the solution. At pH 3·0 a very noticeable stimulating effect occurred with 3 parts per million of aluminium.

In the experiments of McLean and Gilbert[12] the plants were placed alternately between complete nutrient solutions containing phosphate and complete nutrient solutions without phosphate, but containing aluminium. The pH of these solutions was kept at 4.0–4.5·. Thus the effects of phosphate starvation and increasing acidity were obviated. The results of these studies showed that lettuce, beet, and barley were very sensitive to aluminium, whereas maize, turnips, and redtop were fairly resistant to aluminium poisoning.

The symptoms of aluminium poisoning of plants are apparently seen first in the dwarfing and injury to roots accompanied by a decreased permeability of the plants to dyes or nutrient solutions.

ALUMINIUM IN ANIMALS.

Owing to the minute amounts of aluminium usually present in animal tissues and the relative insensitivity of the methods used for its estimation, the results of earlier analysts are not dependable.

Myers and Morrison (1928)[13], using a sensitive colorimetric method, found traces of aluminium in the tissues of the dog. Of the tissues analysed—heart, kidney, spleen, and liver—the latter was found to contain the largest amount (15 mgms. Al per 100 gms.). Human autopsy tissue[14] was also examined, the figures obtained being of the same order as those found for the dog. Lewis[9], using the spectroscopic method, was unable to detect aluminium in human blood, except in certain cases after the subjects had been fed on an aluminium rich diet, when minute traces of this element were indicated. Sheep's blood, on the contrary, was found to contain from 1 to 1½ parts per million of aluminium.

From the numerous metabolism experiments conducted on various animals including man, it would appear that the amount of aluminium absorbed from an aluminium rich diet is very small, and little if any of this element is stored up in the tissues. Aluminium in small amounts is evidently not toxic; very large amounts may, however, produce mild catharsis.

Experimental.

I. *The Estimation of Aluminium in Pastures.*— Experience in this laboratory has led the author to the conclusion that the gravimetric methods ordinarily employed for the estimation of aluminium, while doubtless accurate for appreciable quantities of this element, are not suitable for pasture analysis where the aliquot solution taken frequently contains less than several milligrams of aluminium. Rather than use an inconveniently large aliquot it seemed preferable to examine the possibilities of the colorimetric methods for the determination of aluminium.

A study of the literature showed that two colorimetric reagents for the estimation of aluminium were available—sodium alizarin sulphonate and aurin tricarboxylic acid. The second reagent has found favour with many analysts, and for some years past the conditions and characteristics of the aluminium lake have been examined. Quite recently Lampitt and Sylvester[8] have proposed the use of aurin tricarboxylic acid in conjunction with the Lovibond tintometer for the determination of aluminium in foodstuffs. Their method is claimed to be accurate and, with certain slight modifications embodied in the procedure described below, was found quite suitable for the estimation of aluminium in pastures.

Analytical Procedure.

a. *Preparation of the Solution.*—For the approximate determination of aluminium the following preliminary preparation is sufficient. Measure a suitable aliquot* of the pasture solution into a 100 c.c. beaker, and take just to dryness on the water bath. Add 2 c.c. 5N hydrochloric acid and 5 c.c. of water. Warm for about one minute and shake to dissolve any precipitate. It will be seen from Table I that this procedure may give a low figure owing to interference by

* Enough to give from 1.8 to 6.0 red units.

other substances. For strictly accurate work the following modification was found satisfactory. Add one drop of methyl orange indicator to the aliquot and dilute to 15 c.c. Exactly neutralise this solution with 5% ammonia, boiling the solution to remove any slight excess of ammonia. Allow the solution to stand for at least an hour and then filter through a Whatman No. 42 paper, washing the precipitate with cold water. Dissolve the precipitate back into the precipitation beaker with hot 25% hydrochloric acid. Take solution just to dryness on the water bath. Add 2 c.c. 5N hydrochloric acid and 5 c.c. water. Warm to dissolve the precipitate.

b. *Development of the Colour.*- Add 30 c.c. of the colorimetric reagent, mix thoroughly, and place beaker in water bath for 5 minutes. Cool solution in running water for at least 5 minutes. Add 3 c.c. of ammonium hydroxide–carbonate reagent to a 50 c.c. standard flask. Wash the solution into the standard flask and make up to the mark with distilled water, mixing the contents thoroughly.

c. *Measurement of the Colour.*—Add 30 c.c. of the solution from the standard flask into the Lovibond tintometer tube. Match the colour and read off the red units on the Lovibond scale exactly 5 minutes after neutralisation of the solution with the ammonium hydroxide-carbonate reagent. The amount of aluminium is then ascertained directly from a graph constructed from measurements on known amounts of the standard aluminium solution

Reagents.

1. 5N hydrochloric acid.

2. 5% ammonia solution.

3. Colorimetric reagent. This must be prepared immediately before each series of determinations. Mix one part by volume of 5N ammonium acetate with 4 parts of 50% glycerine and finally add 1 part of a 002% solution of aurin tricarboxylic acid exactly neutralised with ammonia.

4. Standard aluminium solution. Dissolve 1 757 gm. of pure potash alum $Al_2(SO_4)$, $3K_2SO_4$, $24H_2O$ in distilled water containing 25 c.c. of 5N hydrochloric acid. Make solution up to 1 litre. Dilute 5 times to give a standard solution of which 1 c.c. = 0 02 mgm. of aluminium.

5. Ammonium hydroxide–carbonate solution. Mix equal volumes of 10N ammonium hydroxide solution and 2N ammonium carbonate. Keep the mixture in a well-stoppered bottle.*

II. *Accuracy of the Method.*—The accuracy of the method was checked by a comparison with the colorimetric and gravimetric determinations on the same series of pastures solutions and by the recovery of aluminium added in known amounts to a synthetic solution prepared from pure analytical reagents.

* It is recommended that the reagents should be occasionally checked with the standard aluminium solution to ensure that no deterioration has taken place.

TABLE I.—A Comparison of the Gravimetric and Colorimetric Methods of Estimation of Aluminium in Pastures.

Lab. No.	Species.	% Alumina.		
		Gravimetric.	Colorimetric.	
			Determined directly in presence of other mineral constituents.	Aluminium first precipitated by ammonia in the presence of phosphate.
7102-3-4	Danthonia (com	0.040†	0.026	0.028
Duplicate	posite sample)	0.032	0.025	0.032
7187 8-9	Danthonia (com-	0.055	0.048	0.052
Duplicate	posite sample)	0.047	0.046	0.054
7561	General pasture	0.090	—	0.092
7304	General pasture	0.140	0.090	0.095
Duplicate	General pasture	0.152	0.100	0.086
7369	General pasture	0.020	—	0.024
7373	General pasture	0.016	—	0.019
4008	Cocksfoot	0.042	0.037	0.040
Duplicate	Cocksfoot	0.045	—	0.038
2102	Red Clover	0.050	—	0.059
Duplicate	Red Clover	0.052	—	0.064

The gravimetric determinations shown in Table I. involved the precipitation of iron and aluminium with ammonia after the phosphate had been removed. The iron was then determined colorimetrically with thiocyanate and the alumina obtained by difference

It will be observed that the presence of other substances is inclined to give a low figure for the colorimetric estimation. When, however, the estimation is made on the precipitate obtained by neutralising the solution with ammonia in the presence of phosphates there is fair agreement between the gravimetric and colorimetric methods, the agreement of the duplicates on the whole being closer when the latter method is used.

TABLE II.—The recovery of aluminium from a synthetic pasture solution containing:—CaO 1·0 per cent., P_2O_5 0 75 per cent., K_2O 2·62 per cent., Na_2O 0 20 per cent., SO_3 0·82 per cent., MgO 0 40 per cent., Fe 0 007 per cent., and Mn 0·022 per cent.

Aluminium added % Al_2O_3.	Aluminium found % Al_2O_3.
0.095	0.097
0.076	0.080
0.048	0.049
0.038	0.041

The above table shows the method to be accurate to within 5 per cent.

† Weight of precipitate insufficient for accurate determination.

III. *Preparation of the Solution for the Determination of* Aluminium in Pastures.—The two most common methods of preparing plant solutions for the analysis of their mineral content involve either ashing followed by extraction of the ash with hydrochloric acid or wet digestion with some oxidising agent such as nitric and sulphuric acids. As a result of past experience in the analysis of pasture samples in this laboratory it was known that the first method did not completely extract all the iron and aluminium, a certain proportion of these elements being always retained in the siliceous residue. It was not known, however, whether the wet digestion method would effect a more complete extraction of these elements from the pasture, and to test this point a series of determinations involving both methods were made. The results of this investigation are presented in Tables III and IV.

TABLE III.—Iron and aluminium occluded in the crude silica of pastures (Ashing Method).

(All results expressed as percentages of the moisture free grass.)

Lab. No	Sample	SiO	In solution.		Occluded in SiO_2		Total.	
			Al_2O_3	Fe	Al_2O_3	Fe	Al_2O_3	Fe
7430	General pasture	4 49	0 057	0 016	0 019	0.0030	0.076	0 019
7427	General pasture	2 90	0 079	0 022	0 026	0 0070	0.105	0 029
8125	Meadow fescue	4 73	0 056	0 006	0 021	0 0035	0 077	0 0095
8102	Brown-top	9 15	0 074	0 008	0 021	0 0030	0 095	0 011
4069	Cocksfoot	2 31	0 045	0 008	0.017	0 0055	0 062	0 0135

TABLE IV.—Iron and aluminium occluded in the crude silica of pastures (Wet Digestion Method).

(All results expressed as percentages of the moisture-free grass.)

Lab. No.	Sample	SiO_2	In solution.		Occluded in SiO_2		Total.	
			Al_2O_3	Fe	Al_2O_3	Fe	Al_2O_3	Fe
4068	Cocksfoot	2.3	0.016	0.005	0.030	0.0035	0.046	0.0085
4069	Cocksfoot	2.4	0.022	0 0075	0.018	0.005	0.040	0 0125
7427	General pasture	3 7	0.042	0.015	0.032	0.007	0 074	0 022
7430	General pasture	4.05	0.036	0 014	0.020	0.004	0 056	0.018
8102	Brown-top	8.95	0.025	0.008	0.021	0.004	0 046	0 012
8114	Lotus major	0.23	0.019	0.008	0.015	0.006	0.034	0.014
8125	Meadow fescue	4.6	0.021	0.006	0.021	0.004	0.042	0.010

The results shown in Table III were obtained from pasture samples which had been picked over to remove stalks and obvious contaminating material before grinding in a special bronze mill. The preparation of the pastures for wet digestion involved a preliminary brushing to remove any adhering soil, consequently the alumina figures are somewhat lower than for the ashing method.

It will be seen from the above tables that percentage of siliceous residue and occluded iron and alumina is nearly the same for both the ashing and the wet digestion methods. Approximately 35 to 65 per cent. of the total alumina and 25 to 40 per cent. of the total iron estimated on the cleaned pasture are held up as part of the insoluble residue It would be interesting to investigate whether the insoluble iron and aluminium occurs as such in the pasture, or whether in the process of wet digestion or of ashing an insoluble silicate is formed. In this connection it is noteworthy that Sjoman[16] has shown that when quartz and iron oxide are heated together, the Si atoms in the SiO_2 lattice are partly replaced by Fe atoms.

Since the method of wet digestion appeared to offer no advantages over the ashing method, it was decided to adhere to the standard procedure practised in this laboratory. The air-dried pasture was ashed in a porcelain dish at a temperature not exceeding dull red heat, and the residue was taken to dryness twice with hydrochloric acid to render the silica insoluble. Next the mineral constituents were taken up with hydrochloric acid and allowed to stand for 24 hours after which the crude silica was filtered off. The latter was then ignited and again extracted with hydrochloric acid for 24 hours and finally filtered, the filtrate being combined with the first filtrate. In order that the estimations might be comparable with those previously obtained in this laboratory the iron and alumina in the insoluble residue were not estimated.

IV. *The Distribution of Aluminium and Iron in Grasses and Legumes.*—The distribution of aluminium and iron in grasses and legumes was studied primarily to compare the concentration of these elements in those parts of the plant which are protected from dust contamination, such as the stem of the toetoe *(Arundo conspicua)* after the outer sheath has been stripped, with the concentration in those parts where contamination is unavoidable, as, for example, the roots and leaves. The data obtained are collected in Table V. All samples were carefully washed with distilled water to remove any adhering soil and, as an extra precaution, the roots in addition to being washed with distilled water were carefully scraped to remove the outer surface.

TABLE V.—The distribution of aluminium and iron in grasses and legumes.

(All results expressed as percentages of the moisture-free material.)

Sample	Al_2O_3		Remarks
Bamboo—			
Roots	0·026	0·010	Local sample, grown
Stem	0·0025	0·0017	on hillside in dry
Leaves	0·017	0·0081	locality.
Pampas-grass (*Gynerium argentium*)-			
Roots	0·052	0·027	Local sample, grown
Stem	0·0031	0·0020	in dry locality.
Plume	0·010	0·0043	
Leaves	0·009	0·0052	
Toetoe (*Arundo conspicua*)—			
Stem	0·010		Local sample, grown
Plume	0·019		on sandhills.
Leaves	0·032		
Ryegrass—			
Root . .	0·114	0·090	Greenhouse sample.
Leaves	0·010	0·018	Scanty growth.
Red clover—			
Root	0·104	0·022	Local sample.
Leaves and stem	0·052	0·018	Rank growth.
White clover—			
Stem	0·033	0·011	Local sample, grown
Leaves	0·035	0·022	on sandy soil.
Flower	0·085	0·043	

It will be observed from Table V that while aluminium occurs in appreciable amounts throughout all parts of the grasses, the highest proportion is found in the roots, the stems being relatively deficient in aluminium as compared with the plumes and leaves. From the limited number of observations made it would seem that clovers differ from grasses in their higher average aluminium content in the above-ground portion.

In both grasses and clovers the distribution of iron appears to follow approximately that of the aluminium.

V. *The Effect of Cleaning on the Aluminium and Iron Content of Pastures.*—In this investigation the samples representing slightly, medium, and heavily contaminated pastures were taken respectively from the Rotorua, Taranaki, and Morton Mains districts.

After picking over the air-dried pasture to remove woody stalks and obvious contaminating material according to the usual practice of this laboratory, a suitable aliquot (about 40 grams) was set aside and thoroughly brushed to remove as completely as possible any loosely adhering soil and dust. A weighed amount of the brushed

pasture was then placed in a 10-inch porcelain basin and washed with distilled water. After about five minutes' agitation the water generally became discoloured owing to the suspension of clay and soil particles. The whole of the sample was then removed and placed in a clean basin of distilled water, the process being repeated as before until such time as the water showed no appreciable amount of suspended matter. In the case of the Morton Mains pastures, a certain amount of clay adhered very firmly to the grass-blades, necessitating a preliminary soaking for one hour with distilled water.

TABLE VI.—The effect of cleaning on the alumina and iron content of pastures.

(All results expressed as percentages of the moisture free pasture.)

No. Lab.	Sample	Standard Procedure.		Pasture brushed.		Pasture washed with water.		Locality.
		Al_2O_3	Fe	Al_2O_3	Fe	Al_2O_3	Fe	
2102	Red clover	0.051	0.009	0.025	0.008	0.017	0.0055	Kaharoa, Rotorua.
4069	Cocksfoot	0.045	0.008	0.019	0.006	0.006	0.0055	
8120	Poa pratensis	0.022	0.010	0.018	0.009	0.007	0.006	
8122	Meadow foxtail	0.022	0.009	0.024	0.0085	0.022	0.0085	
8127	Ratstail	0.029	0.007	0.028	0.007	0.013	0.0045	
8137	Chewings fescue	0.049	0.012	0.010	0.011	0.0095	0.011	
7427	General pasture	0.079	0.022	0.038	0.013	0.023	0.010	Te Popo, Taranaki,
7430	,,	0.057	0.016	0.029	0.010	0.018	0.009	
7493	General pasture	0.40	0.083	0.11	0.066	0.039	0.017	Morton Mains, Southland.
7494	,,	0.65	0.22	0.18	0.12	0.15	0.062	
7495	,,	0.16	0.032	0.030	0.018	0.022	0.015	
7497	,,	0.35	0.21	0.20	0.12	0.051	0.023	

It will be seen from the results presented in Table VI that washing is more effective than brushing in the removal of contaminating material from the pasture. It was thought, however, that the former method might not be valid owing to the possible extraction of the pasture minerals.

Accordingly, the solubilities of the chief inorganic constituents were tested as follows. 20 grams of air-dried pasture were shaken up with 500 c.c. of distilled water for 20 hours, 1 c.c. of toluene being added to inhibit bacterial action. The solution was then quickly filtered once through a Whatman No. 41 filter paper and finally through a No. 42 paper. The results of this investigation are collected together in Table VII.

TABLE VII.—The solubility of the chief inorganic constituents of pastures in water.

(All results expressed as percentages of the moisture-free pasture.)

Lab. No.	Species	Total Mineral Content.							Water Soluble Mineral Content.							pH Indicator Mthd.	Water sble. acids pr 100 gms. Air-dried pstre
		CaO	P_2O_5	K_2O	Fe	Al_2O_3	Mn	MgO	CaO	P_2O_5	K_2O	Fe	Al_2O_3	Mn	MgO		
4068	Cocksfoot	0.41	0.72	3.16	0.006	0.044	0.046	0.34	0.27	0.55	2.64	0.0007	none	0.0052	0.17	5.5	= 19.9 c.c. N. NaOH.
7427	General pasture	1.41	0.40	1.84	0.022	0.079	0.014	0.49	0.32	0.32	1.50	0.0009	trace	0.0026	0.22	5.0	= 18.7 c.c N. NaOH.
7430	,,	0.78	0.42	1.72	0.016	0.057	0.009	0.41	0.10	0.36	1.70	0.0006	..	0.0034	0.18	5.5	= 16.2 c.c. N. NaOH.
8114	Lotus major	0.90	0.61	3.18	0.012	0.074	0.011	0.70	0.28	0.42	2.63	trace	none	0.0018	0.37	4.5	= 26.7 c.c. N. NaOH.
8120	Poa pratensis	0.56	0.65	2.00	0.010	0.074	0.018	0.45	0.26	0.50	1.80	0.0004	.	0.0039	0.30	5.5	= 18.5 c.c. N. NaOH.
8137	Chewings fescue	0.58	0.71	2.43	0.012	0.049	0.046	0.23	0.24	0.54	2.08	0.0008	..	0.0086	0.17	6.0	= 18.2 c.c N. NaOH.

TABLE VIII.—The solubility of the chief inorganic constituents of pastures in water.

(Each result expressed as a percentage of the corresponding total inorganic constituent.)

Potash (K_2O)	Magnesia (MgO)	Manganese (Mn)	Aluminum (Al)	Phosphate (P_2O_5)	Lime (CaO)	Iron (Fe)
82·99%	14·74%	11·38%	trace %	69·80%	12·66%	trace 11%

The practice of steeping pastures in water to remove earthy material evidently leads to the extraction of some of the major constituents as is shown from Table VIII. So far as iron is concerned, however, this element is only slightly soluble, so that washing of the pasture should not extract any appreciable amount, especially if the process occupies only a few minutes. Moreover, it is unlikely that any iron is dissolved out from the pasture in the ferrous state and subsequently oxidised and precipitated in the solution as ferric hydroxide, since solubility experiments conducted entirely in an atmosphere of nitrogen gave the same results for the solubility of iron as those conducted in air. Thus while the method of washing the pasture renders the sample unsuitable for a general analysis of the mineral content, it affords a satisfactory means of estimating the true pasture iron in a contaminated pasture sample.

A noteworthy feature arising from Table VII is the remarkable difference in the solubility of the same mineral constituent in different pastures, particularly in the case of lime. This would seem to suggest that a pasture with a high lime content might not necessarily contain as much digestible lime as a pasture with much less total lime.

VI. *The Availability of the Pasture Iron in Pepsin-Hydrochloric Acid Solutions.*—As it had been suggested by Askew and Rigg[1] that bush sickness might be caused by a soil iron deficiency rather than by a deficiency of iron in the pasture, it seemed desirable to obtain some data regarding the digestibility of iron in contaminated and uncontaminated pastures. In the absence of facilities for the carrying out of metabolism experiments a series of contaminated and uncontaminated pastures were digested in pepsin-hydrochloric acid solution. The experiments were conducted as follows. A weighed amount of air-dried pasture, approximately 5 grams, was placed in a beaker with 400 c.c. of 0·35 per cent. hydrochloric acid solution containing 0·2 per cent. pepsin and warmed for six hours at a

temperature of 37° C. Throughout the experiment the solution was stirred to secure a more complete reaction. At the end of the period the solution was filtered and evaporated to dryness. After igniting the extract, the ash was analysed in the usual way. The preparation of the pastures for the pepsin-hydrochloric acid consisted of a preliminary picking over to remove stalks and obvious contaminating material according to the usual practice, except that the air-dried grass was not ground.

TABLE IX.—The digestibility of iron in contaminated and uncontaminated pasture samples.

(All results expressed as percentages of the moisture free grass.)

		Standard procedure.	Cleaned pasture.	Soluble in Pepsin hydrochloric acid.	
Lab. No.	Species	Fe	Fe	Fe	Locality
8114	Lotus major	0.008	--	0.007	Kaharoa,
8120	Poa pratensis	0.010	0.006	0.0035	Rotorua.
8137	Chewings fescue	0.012	0.011	0.004	
7427	General pasture	0.022	0.010	0.012	Te Popo,
7430	" "	0.016	0.009	0.0075	Taranaki.
7493	General pasture	0.083	0.017	0.012	
7494	" "	0.22	0.062	0.055	Morton
7495	" "	0.032	0.015	0.006	Mains,
7497	" "	0.21	0.023	0.035	Southland.

Generally speaking, the results shown in Table IX indicate that the percentage of iron soluble in pepsin-hydrochloric acid is high, ranging above 35 per cent. of the true pasture iron. The most striking feature of the table, however, is the fact that even excess iron contamination adds but little to the amount of digestible iron which thus appears to be closely related to the natural iron of the pasture.

In the absence of actual metabolism experiments, it may be tentatively concluded that the digestibility of the pasture iron varies considerably according to the species of the grass, and that probably but little of the contaminating iron is available to the animal.

GENERAL DISCUSSION.

The results obtained on carefully cleaned pastures support the conclusion that most of the aluminium ordinarily found in pastures is due to soil contamination. This is a matter of some importance in the assessing of the food value of the iron, as pepsin-hydrochloric acid digestion experiments on contaminated and uncontaminated pastures suggest that whereas the natural pasture iron is readily soluble, the iron contributed by soil contamination is by no means

easily digestible, and hence the interpretation of the mineral content analysis requires that some allowance be made for the contamination factor.

The alumina content of clean pastures generally falls below 0·025 per cent. of the moisture-free pasture, and the excess alumina above this limit might therefore be attributed to soil contamination. It must be remembered, however, that acidity favours the absorption of iron and aluminium by the plant, and that while the limiting factor of 0·025 per cent alumina might be given to Te Popo and Kaharoa pastures where the acidity of the soil usually ranges round about pH 5·7 and pH 5·5 respectively, such a factor might not apply to soils whose acidity falls outside the minimum solubility range for alumina defined by Magistad[11] as extending from pH 4·7 to pH 8·5

Attention should perhaps be drawn to the excessive iron and alumina content of some of the Morton Mains pastures; one carefully cleaned sample, for example, contained approximately ten times the normal amount of both iron and aluminium. Moreover, it is probable that the iron and aluminium reported was not due to contamination, since further cleaning of the pasture failed to effect any appreciable reduction in the amounts of these elements. Further experiments are being made to account for this abnormality. In the meantime, it is tentatively suggested that the relatively high acidity (pH 5·1) of the Morton Mains soil from which this last pasture sample was taken might account for the abnormal absorption of iron and aluminium.

Summary and Conclusions.

(1) A modification of the Lampitt and Sylvester method suitable for the estimation of aluminium in pastures is described.

(2) The modified method is found to be accurate to within about 5 per cent., the agreement of duplicate determinations being closer by this method than by the gravimetric method ordinarily used.

(3) The destruction of the organic matter in pastures either by ashing or by nitric and sulphuric digestion leaves from 35 to 65 per cent. of the total pasture alumina and from 25 to 40 per cent. of the total pasture iron in the insoluble residue.

(4) The distribution of aluminium in the bamboo, pampas-grass, toetoe, ryegrass, red clover, and white clover has been studied, the amounts of alumina found varying from 0·0025 per cent. in bamboo stems to 0·114 per cent. in ryegrass roots.

(5) The alumina of the grasses studied is shown to be concentrated chiefly in the roots, the plumes and leaves containing more alumina than the stems.

(6) The figures obtained on carefully cleaned pastures show that, generally speaking, the alumina content is below 0.025 per cent., supporting the idea that most of the alumina ordinarily found is due to soil contamination.

(7) Alumina appears to be the best index of soil contamination in pasture samples, especially contamination from fine atmospheric dust which may not be easily detectable by other methods.

(8) In the estimation of iron the problem of soil contamination is best overcome by brushing and careful washing of the pasture prior to ashing.

(9) Experiments show that this process does not invol
appreciable loss of pasture iron. The washing of pasture/e any
them unsuitable for a general estimation of the miner;s renders
the major ingredients of the pasture, i.e., K_2O, P_2Oal content as
are so combined in the plant as to be largely extract. CaO, MgO,
ble by water.

(10) Digestion of contaminated and uncontamin
in pepsin-hydrochloric acid shows that the amount of ted pastures
which usually exceeds 35 per cent. of the true pasture irsoluble iron,
related to the amount of true pasture iron and is practically independent of the amount of contaminating iron.

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The Geology of the Region about Preservation and Chalky Inlets, Southern Fiordland, N.Z.

PART II.

THE EVOLUTION OF THE MODERN TOPOGRAPHY.

By W. N. BENSON, J. A. BARTRUM, and L. C. KING.

[*Read before the Wellington Philosophical Society, 11th October, 1932; received by the Editor, 12th October, 1932; issued separately, May, 1934.*]

CONTENTS.

Advance Summary.

The development of the present land forms presents a complex problem which requires detailed analysis and consideration of alternative explanations. To clarify the statement of the various lines of evidence, the following general conclusions are given in advance:—

1. The whole Fiordland region was reduced to a peneplain surface either in Cretaceous times, as usually held, or, as now seems more probable, during the later part of the Tertiary period. In its present elevated position the surface then formed is hereinafter termed the Fiordland Peneplain.

2. Before the peneplanation, if it occurred in Tertiary times, but after it if in the Cretaceous, the region was raised early in the Tertiary period with a marginal seaward downwarp. Dissection and marine erosion took place, followed by subsidence, resulting in the deposition of coarse arkosic sediments succeeded by finer and more or less calcareous beds.

3. Renewed elevation was accompanied by marginal corrugation along north-west–south-east axes and development of north-east–south-west undulations. The synclinal axes of the two series cross one another at the sites of the present Preservation and Chalky Inlets.

4. Consequent drainage systems developed in the north-east–south-west synclines, and eroding headward into the rising Fiordland region tended to become adjusted to the structures therein. The controlling structures were the faults, shatter-zones, or joints in the slates, schists, and plutonic rocks. On the hypothesis of the late Tertiary origin of the Fiordland Peneplain, the major planation occurred at this stage and was followed by further uplift. On the hypothesis of the Cretaceous age of the Fiordland Peneplain, the uplift and dissection of the region after the deposition and folding of the Tertiary sediments was a continuous process.

5. While dissection of the uplifted peneplain progressed in the headward portions of the main valleys, the intervening coastward slopes of the peneplain were considerably reduced, with the production of a relatively low and undulating strip of land extending ten miles or more back from the shore, a foothill region in front of the residual promontories of the peneplain. Slow and moderate subsidence then followed, permitting the planing of this lowland region by wave-action during the transgression of the sea over it. Accompanying this there was necessarily much deposition of detritus in the submerged valleys. Such subsidence continued until the original surface of the peneplain in the region discussed in this paper had been lowered to within about 2000 feet of the sea-level, and remained in that position long enough to permit the destruction and disappearance of nearly all of the sea-cliffs cut by the advancing sea, while the main valleys became matured for a long distance inland.

6. Then a movement of elevation commenced which raised the inner margin of this wave-planed strip to a height of about 1500 feet above the sea. It may indeed have been a gentle arching, for the surface of the plateau is convex east of Puysegur Point, though this is possibly better explained by decrease in the rate of submergence towards the end of the previous phase of movement, and, consequently, the more nearly horizontal extension of the wave-planed surface, which is visible in some though not in all parts of it. The smoothed raised surface thus laid bare will hereinafter be termed the "Coastal Plateau." It is perhaps possible that its uplift was accompanied or followed by a revival of old lines of fracture and the subsidence of certain crust-blocks, which may have taken a part in the formation of the present broad depressions in the coastal plateau, namely Preservation Inlet, with Otago's Retreat, and the Western and Eastern parts of Chalky Inlet, with Southport. If that were the case, the two larger islands and Gulches Peninsula remained as horsts between these depressions. It does not appear clear, however, that such differential crust-movements occurred.

7. As the uplift began, streams leaving the margin of the Fiordland Peneplain extended their courses over the emerging coastal plateau. The major streams re-occupied their earlier recently-infilled valleys, from which they speedily removed the detritus, thus bringing about a rejuvenation that finally led to a perfecting of earlier adjustment to structure, which may perhaps have been favoured by the accompanying revival of movement along the early lines of fracture. The intervening minor streams entrenched their consequent extended courses in deep canyons across the plateau, discharging into the open sea.

8. At the commencement of the Pleistocene period glaciers moved down the main valleys, overwhelmed the islands in the inlets, and overflowed on to the coastal plateau on which there were deposited sheets of morainic and outwashed material. It is difficult to estimate how much of the lowering of the land surface should be assigned to preglacial erosion and how much to glaciation or to crustal movement. At all events, at the retreat of the ice the removal of detritus from the valleys was completed and benches along their sides were much modified. Further, the Sounds had a depth comparable with their present depth, whilst masses of moraine lay plastered on the sides of the inlets and probably also formed much of the thresholds at their mouths, and together with some outwash material covered portions of the coastal plateau.

9. Post-glacial activities have been:—

(a) A very small amount of stream erosion within the Sounds and much dissection of the morainic sheet on the coastal plateau. Delta-accumulation is well displayed in some of the Sounds.

(b) Cliff-recession under wave attack with the transport of detritus and morainic material and further growth of the thresholds, building of spits, tying of islands, and levelling of the sea-floor.

(c) Depression of the coast to some extent.

(d) A rather smaller elevation with brief still-stand intervals about fifteen and forty feet above the present sea-level. It is not possible at present to determine the sequence of events in (c) and (d).

The Fiordland Peneplain.

The most striking feature of Fiordland topography is the accordance of summit-levels. There has been a general acceptance of Andrews' (1905) view that "from Milford Sound to Preservation Inlet the even topped ridges . . . appear to represent the survivals of a former huge plateau decreasing from a height of 6000 feet at Te Anau and Milford" as it is traced towards Preservation Inlet. Daly (1912) has argued that accordance of summit-level in the Cordillera of British Columbia, a region analogous climatically and structurally to Fiordland, may result from a complex process of "equiplanation" in which the isostatic depression of salient masses, the concentration of weathering and erosive activities on the higher peaks, and the checking of such activities beneath the tree-line, together with the compound processes of river-spacing and slope-gradation play the chief rôles, but this view has not many supporters. The development of accordant summit-levels during the present geographical cycle by the equiplanation of a region of highly irregular relief would demand an equality of result in spite of diversities of structure and stream-spacing that seems beyond the bounds of probability. Gilbert's (1904) account of a similar region in Alaska is most apposite in its application to Fiordland. "The approximation of summit-heights to uniformity is too close to be accounted for without the hypothesis of an uplifted plain, but the departures from uniformity indicate that little if any of the original plain survives." The dissection of the Fiordland Peneplain about Preservation Inlet (and, indeed, in general) is complete. Nevertheless, the thick-line profile (Plate 2 D), taken from Windsor Point north-eastwards along the crest-line east of Long Sound and Longburn, illustrates the degree of uniformity of summit-levels in the higher parts. Plotted against this is the thin-line profile along the crest-line south of Dusky Sound together with two other profiles parallel thereto between Dusky and Breaksea Sounds along the lines shown in Text-fig. 2, Part I. These three profiles have been based on Preston's (1929) unpublished topographic map of Dusky Sound made available through the courtesy of the Surveyor-General. The accordance of summit-levels is very marked, and their continuity with the general level of the Fiordland Peneplain as far north-east as Milford Sound and Lake Wakatipu is demonstrated by Plate 2, figures B and C. Thus the acceptance of Andrews' general conclusion by Marshall (1905), Park (1909), Speight (1910), and Gregory (1913) seems to have been well founded As will appear, however, Andrews' first impression that the peneplain descended to an elevation of only 1000 feet at Preservation Inlet cannot be supported. Its south-western limits are in the Bald Peaks, Treble Mountain, Mount

Bradshaw, and Resolution Island at a level of a little over 3000 feet, and between it and the sea lies the coastal plateau, commencing at the foot of the above-named points at an elevation of over 1500 feet and descending smoothly towards the sea, ending abruptly in a line of cliffs. The higher and more extensive level has been termed the Fiordland Peneplain, a descriptive term free from any implication which may be involved in the use of Park's (1921) term "Tahora."

It should be noted, however, that the term "Fiordland Peneplain" has here been employed for the sake of brevity and in deference to previous usage (Andrews 1911, Park 1921). But unless it be qualified by the words "thoroughly dissected," it fails to describe the land-surface to which it refers. Indeed, the former existence of a peneplain is only an inference from the marked accordance of summit-levels, which apparently was all that Andrews (1906) had in mind when speaking of "numerous sub-horizontal masses," though he also spoke of the survival of "ridges *and mesas.*" So far as has been gathered from a study of many photographs obtained by alpinists in various parts of northern Fiordland and north-western Otago, only very rarely is there any hint of the presence of flattish areas near the summit-levels which might be considered to be residuals of an original peneplain surface. Such exceptional residual surfaces may be represented by the Bryneira Range, immediately east of the middle portion of the Hollyford River, which range Professor Park has described (1921) as "flat-topped." But though the summit-level of the Barrier Range at the head of the Dart River is remarkably uniform, panoramic views of it obtained from two different directions do not reveal any noteworthy area of sub-horizontal surface. There is, therefore, insufficient evidence to indicate precisely the form of the original surface, and it might be better to substitute for the word "peneplain" Willis' (1928, p. 493) new term "matureland," with the qualifying adjective "subdued" to denote its approximation to a peneplain. "A subdued matureland, thoroughly dissected and subsequently heavily glaciated" would thus be perhaps the nearest approach that can be made at present to an exact explanatory descriptive term for the land-surface to which for the sake of simplicity we here refer as the "Fiordland Peneplain."

The age of this surface demands discussion. It has been customary to consider it of Late Cretaceous age, following the views of Speight (1915), Cotton (1916), and others, though Park (1921) has argued that the planation was complete in Middle Cretaceous times. On this surface, it is held, were deposited Cretaceous and Tertiary sediments, portions of which still remain as outliers, especially where they have been warped and faulted down into low-lying situations. Nevertheless, Marshall (1918) briefly indicated that peneplanation of the schists of eastern Otago had been accomplished in Late Tertiary times, and that the surface so formed has since been locally warped. Benson's unpublished studies of the Dunedin district have revealed two distinct peneplain surfaces. The dissected lava-flows of this region rest on a peneplain-surface cut obliquely across

a series of Middle and Lower Tertiary marine sediments which in turn rest on a Cretaceous peneplain cut in schist. The warping of the Late Tertiary peneplain is here very considerable, but diminishes when traced into north-eastern Otago, where the two peneplain surfaces have been recently described by Service (1933). In North Taranaki (Grange 1927), in the region near East Cape (Ongley and Macpherson 1928), and in North Auckland (Cotton 1922), the peneplanation of the soft Tertiary sediments is now recognised, and in all these districts the Late Tertiary peneplain has been dislocated by warping or faulting. It is therefore difficult to prove in most cases whether the exposed surface of the oldermass is merely the ancient pre-Tertiary surface stripped of its cover, as is commonly assumed, or a new erosion surface cut in the older rocks during the planation of the Tertiary beds, which intersect the pre-Tertiary surface with varying degrees of obliquity, as in the conception of intersecting peneplains implied in the explanatory descriptive term " morvan " introduced by Davis (1912).

It is obvious that planation of soft Tertiary sediments might be accomplished within a period too short to permit of the complete reduction of more resistant formations, but there is weighty, though not unanimous, opinion that extensive planation of hard formations has been produced within Late Tertiary times under climatic conditions not greatly different from those which existed in Fiordland. Thus Smith and Willis (1903) held that the accordance of summit-levels on the Cascade Mountains of the north-west of the United States gave evidence of a peneplain cut in Pliocene times in a complex of granites, schists, Palaeozoic (?), Cretaceous, and even early Tertiary folded sediments and lavas. This surface was then elevated and warped, the consequent streams were very maturely developed, and an early mature topography was superinduced by rejuvenescence following on further uplift. R. T. Chamberlin (1919) arrived at a like conclusion concerning the age of the rather imperfect peneplain cut out of the granites, etc., forming the Rocky Mountains of Colorado. This peneplain had been recognised by Davis (1911) and referred by Finlay (1916) to an Oligocene age. Daly (1912) argued that comparison with the Appalachian region made it improbable that its reduction to the present general summit-level could have been accomplished as late as Pliocene time, but Johnson's recent interpretation of Appalachian topography greatly weakens this argument. " During the Tertiary came the . . . long cycle or cycles of erosion ending in the production of the remarkable, well-developed, and widespread Schooley Peneplain which bevels both the ancient crystallines and the (Cretaceous) coastal plain deposits," and three successive elevations have since lead to the development of two lower peneplains on the weaker formations and the final entrenchment of streams (Johnson 1931). Atwood and Mather (1932) have concluded that in Colorado the peneplanation of a complex of crystalline rocks, Palaeozoic and Mesozoic sediments, and Tertiary volcanic rocks was accomplished during the Pliocene period (monadnocks of the harder rocks being left), and that there followed after a gentle doming a

long complex history of profound dissection during the Quaternary period. In Europe, Brückner (Penck and Brückner 1909, pp. 476-9) describes the Pliocene planation of the Jura Mountains.

Much other literature on this topic might be cited, from which it would appear that Late Tertiary peneplanation of the Fiordland region is at least worthy of discussion. Two direct lines of evidence bearing thereon may, therefore, be considered.

In the neighbourhood of Preservation Inlet the Coastal Plateau has obviously been cut across the folded Mid-Tertiary strata and into the slates and granites (see Plate 2 E). The basal Tertiary beds, dipping at angles of 20° or 30°, approach within five miles of the summit of Bald Peaks, whence there extends away to the north-east the even, gently ascending summit-level of the Fiordland Peneplain. The conventional hypothesis would regard that summit-level as representing the surface on which the Tertiary beds were deposited, but unless the corrugation of the pre-Tertiary surface died out completely in the intervening five miles, the Fiordland summit-level would seem to truncate the pre-Tertiary land-surface (see Part I, Plate 43, Section; and Plate 3 E). Moreover it has been shown (Part I, p. 428) that the surface on which the basal Tertiary beds rested could not have been a peneplain, but possessed considerable relief.

More striking is the occurrence of a long, steeply-dipping strip of marine Tertiary rocks infaulted among the semi-schistose Palaeozoic (?) sediments at Bob's Cove on Lake Wakatipu and extending for at least fifteen miles northward (McKay 1880, Park 1909).* The age of these rocks has not been ascertained precisely, but they belong to the Oamaruian system of approximately Oligocene-Miocene age. Originally resting on the schist, they have been dragged down to a depth of about five thousand feet along a fault-plane. The general relations, topographic and geologic, are shown in Plate 2, A, C, and F. The last figure is copied in part from Professor Park's (1909) section, but has been modified to indicate the hypothetical former position of the Tertiary beds. Whatever may have been the original disposition of the various formations, it would seem that the faulting that could bring the Tertiary beds into their present position could not have been accomplished without a relative displacement of the formations on either side of the fault-plane that would have had a vertical component amounting to several thousand feet. Nevertheless, the accordance of summit-level continues unchanged across the fault-line, and the infaulted strip crosses the flanks of the mountains, and does not follow any valley or fault-angle depression. The suggestion seems very strong that the Fiordland Peneplain truncates the faulted Tertiary rocks, and was, therefore, formed after a considerable crust-movement involving Mid-Tertiary formations. Further, the occurrence of major earth-blocks such as the Remarkables or Cromwell Flat, elevated or depressed in relation to the general summit-level, appears to indicate

* This region is now being examined in detail by Mr C. O. Hutton.

that block-faulting of the Fiordland Peneplain occurred in very late Tertiary or even Pleistocene times. In this connection it may be suggested that the development of Tertiary sediments at Bob's Cove, so much wider than elsewhere even at higher elevations along the fault-line, lends support to the suggestion that the rocks here have been let down by transverse W.-E. trough-faulting, which may have been responsible for the initial formation of the middle portion of Lake Wakatipu itself and the Arrow Basin, both of which have later been modified by erosive processes (cf. Andrews 1911, pp. 135-6).

In putting forward this hypothesis of the Late Tertiary age of the Fiordland Peneplain, it should be noted that Bell and Fraser (1906) suggested that the Wainihinihi Peneplain cut in the schists and early Tertiary (?) rocks of South Westland, was a continuation of the Fiordland Peneplain. This view was at first supported by Morgan (1908), though later he assumed, without very detailed discussion, the pre-Tertiary age of the peneplain (Morgan and Bartrum 1915). Obviously definite conclusions cannot be based only on the facts that are here cited, though it would appear there is a case for the critical revision of the conventional hypothesis concerning the Fiordland Peneplain. The proof of its Late Tertiary age, if obtainable, would have far-reaching effects on the study of the Cainozoic history of the South Island of New Zealand.

On the conventional hypothesis of the pre-Tertiary age of this peneplain, the sequence of events during Tertiary times near Preservation Inlet might be as follows:—The peneplain was uplifted in early Tertiary times with strong marginal downwarpings, but no other dislocation. The marginal slopes were dissected and coarse sediments accumulated at their base. The region now subsided and finer sediments were deposited in a sea which transgressed widely over the peneplain. Uplift again took place, with strong N.W.-S.E. corrugation sharply limited to a narrow strip reaching not more than five miles inland from the present outer coast-line near Puysegur Point. This was crossed almost perpendicularly by a gentle undulation, which was more sharply folded when it reached the site of the present outer coast-line. The induced consequent drainage resulted in the formation of the valleys which debouched where Preservation and Chalky Inlets now open, and stripped the Tertiary sediments from those portions of the area above the then existing base-level (rather more than 1000 feet above the present sea-level).

On the alternative (and preferred) hypothesis of the Tertiary age of the Fiordland Peneplain, the record of Tertiary times might be thus:—In early Tertiary times basal arkosic breccias were deposited around a surface of considerable relief, which became lessened both by subaërial erosion and subsidence or marine transgression in Mid-Tertiary times. Uplift followed associated with marked corrugation on N.W.-S.E. axes in the Preservation Inlet district, together with extensive faulting which lead to the involution of the Tertiary beds among the older formations in the Wakatipu region. The development of the great peneplain then ensued, the erosion surface being formed at a considerable depth below the former level

of the base of the Tertiary beds except in the regions marginal to Fiordland, and adjacent to the infaulted beds. Then renewed uplift occurred, producing a broadly-arched surface gently inclined to the south-west. In the Preservation region a slight almost longitudinal undulation, perhaps on N.E.–S.W. lines determined by the previous undulation, caused the development of consequent drainage-systems where are now the two main valley-systems. On either side of these was formed a narrow partially planated lowland about fifteen hundred feet below the level of the Fiordland peneplain and possibly perfected in its planation by marine erosion.

Whether the Pre-Tertiary age or the Tertiary age of the Fiordland Peneplain be accepted, the Chalky and Preservation drainage-systems may reasonably be considered as consequent on the warped margin of the peneplain. As the drainage-systems became mature, their valleys would tend to adjust themselves to the structures of the rocks that they traversed. As already shown, these rocks had been broken by several systems of shatter-belts, faults, well-marked joint-planes, and other fractures. It is, therefore, desirable to consider whether there be any evidence of such adjustment, which will be done in the following section

THE RELATIONS BETWEEN TOPOGRAPHY AND STRUCTURE.

The major correlation between the synclinal structure and topography of Chalky and Preservation Inlets has just been noted, whilst the anticlinal character of Gulches Head and the existence of several well-marked series of fractures have been discussed in Part I. The minor relations between structure and topography may be indicated by the following parallelisms:—

1. Parallel to those fracture-lines that trend nearly east and west are the following: The upper portion of Gray River, and the shore of Preservation Inlet westward of the same; Dawson Burn, Narrow Bend, and the central trough of Preservation Inlet as shown by the 50 fathom isobath; the ridge of the Cording Islets; Blacklock Stream and the low col leading into the head of Useless Bay opposite thereto; the middle reach of Long Sound; the narrow inlets opening from Cliff Cove, and, as a major feature, Cunaris Sound; the eastern part of Northport and the valleys immediately to the north thereof; probably also the strait between Passage and Chalky Islands. Gregory (1913) indicates that this lineament is seen throughout the south-western portion of Fiordland. Thus the coast-line eastwards from Windsor Point follows this direction, also Dusky Sound and the islands therein, Wet Jacket Arm and Breaksea Sound and streams adjacent thereto. (See Part I, Text-fig. 2.)

2. Parallel to those fracture lines trending approximately north-east–south-west are the following: The western portion of Northport; Edwardson Sound and the eastern entrance to Chalky Inlet; Isthmus Sound, the northern portion of Long Sound and Useless Bay. With these also are to be grouped the three main valleys, Longburn, Carrick River, and the Oho Valley. On the south coast, Lake

Hakapoua and the Upper Kiwi Valley beyond the present district follow this direction, but the apparent parallelism therewith seen in the streams between Kiwi Burn and Otago's Retreat, and on Coal Island, which traverse the Tertiary rocks, may result merely from their consequent courses. Nevertheless, the Tertiary rocks are sharply cut off by Otago's Retreat, which it will be shown is probably a rift.

Beyond the area under study, Cascade Cove entering Dusky Sound and several small streams adjacent thereto, which do not follow the lines of quickest descent, are probably influenced by fractures along this trend line. The Five Fingers Peninsula is most strikingly parallel therewith. The major feature parallel to this line is, however, the general course of the coast from Dusky to Milford Sound, an almost rectilinear coast broken only by the entrances of the various Sounds. It plunges steeply down into deep water, soundings of 188 fathoms and of over 300 fathoms being recorded within a mile of the coast between Daggs and Thompson Sounds. Hector (1863) records that off Nancy Sound the mountains rise from the water's edge with a slope that is rarely less than 25° and often 50° to 60°, but not forming sheer precipices.

Andrews (1907), Park (1910), and Morgan (1929) considered this to be a fault-coast, recency of movement along which may be indicated by the occurrence of earthquakes (Taylor 1855). Its fault-origin has not, however, been accepted without question, and Hutton (1875) gained the impression that its slope was terraced rather than an abrupt scarp. This may not, however, be inconsistent with an origin by repeated movement. On the whole, this north-eastern–south-western direction is the most marked trend in the topography of the region herein considered and is, of course, that of the axis of the South Island of New Zealand.

3. Parallel to the fractures running to the west of north may be noted first the western side of Southport, which clearly follows the Southport Fault and is, as will appear, a fault-line scarp resulting from revival of movement. Again, the southern end of Long Sound and Revolver Bay are enclosed between steep shores parallel to the same direction, whilst Long Island is similarly oriented. Lumaluma Creek entering the head of Edwardson Sound, Duck Cove, and especially Acheron Passage in Dusky Sound are parallel to this group of fractures, and the direction of the coast from Cape Providence to West Cape may also be determined to some extent by structural features following this direction.

4. The most striking topographic feature trending north-west–south-east is the deep through valley between Last Cove, in Long Sound, and Cliff Cove (near the head of Cunaris Sound) on the western side of which is the Last Cove fault. The shores of Last Cove are drift covered, and those of Cliff Cove do not display any marked shatter-zones in this direction, but it seems hardly likely that the association of so low a col with so definite a fault-line can be wholly fortuitous. Again, the south-east trend of the lower part

of West Branch, or Lumaluma Creek, which enters the head of Edwardson Sound, has perhaps been influenced by the strongly developed north-west jointing in that region. The same direction appears, beyond the area mapped, in the trend of the majority of the Sounds, notably Daggs, Doubtful, Nancy, Charles, George, Bligh, Sutherland, and Milford Sounds, and of the north and middle fiords of Lake Te Anau, Clinton River, and Esk River entering South Fiord.

5. Few marked topographic features follow an east–south-east direction within the area mapped, unless the course of Richard Burn entering the head of Long Sound be reckoned as such. In Chalky Inlet the southern coasts of Passage and Great Islands and the adjacent isobathic lines seem to follow this direction, to which also is parallel the shatter-belt nearest to Stripe Head.

Reviewing the statements above, it may be concluded that there are a large number of facts indicative of structural influences in the development of the topography, and of some adjustment of streams to structures.

THE COASTAL PLATEAU.

General Description.

The stereogram (Part I, Plate 41) and profiles (Plate I; Plate 2, B, D, E) of the region under consideration show that the edge of the elevated Fiordland Peneplain is separated from the sea by a lower sloping coastal plateau, a striking feature, which has been described by Hector and McKay. Thus Hector (1863) states concerning the coast between Dusky Sound and Cape Providence, "The shore is bounded by rocky cliffs a few hundred feet in height, from the summit of which there is a gentle slope for a distance of six miles to an elevation of fifteen hundred feet backed by smooth wooded ridges, the summits of which are three thousand feet above the sea. This slope is divided by a stream which comes down to the sea at West Cape . . . and its uniformity is broken by a few sharp cones." Similar features continue east of Preservation Inlet. McKay (1896) notes that "the south coast from Puysegur Point to the Big River presents between the granite mountains and the shore an area five to ten miles in breadth which declines gradually or in terrace-like steps from twelve hundred feet to within two hundred feet of sea-level, the land as a rule terminating in a line of cliffs. Above the general level stands a line of rocky projections which have received the name of hummocks, but which are really hills of considerable size. . . . The passage across it of the several small streams and lesser rivers has been the means of cutting deep gorges and canyon-like valleys, or, in the case of larger streams, broader valleys, the sides of which are sculptured into gullies and ridges." The terraces are, however, evident only in the south-eastern portion of the region, between Wilson's and Big Rivers, where attention was drawn to them by Hutton in 1875, but the present writers had no opportunity of studying them at close quarters.

At Puysegur Point the surface of the plateau is apparently unbroken by terracing, but is convex, its slope near the shore being nearly 6°, but becoming almost horizontal further from the sea (see Plate 2 E). The inner margin of the plateau has the line of "hummocks"* referred to by McKay running near and parallel to it, but is not marked by any abrupt cliffs. There is instead a pronounced change of slope around the base of the Bald Peaks, which may be traced from their south-east to their north-west aspect, and continues to the base of Arnett Peak overlooking the sharp bend in Long Sound, thus leaving a strip of the Coastal Plateau to the east of Revolver Bay which probably reaches over 1500 feet above the sea. It is not possible to recognise any systematic break of slope along the sides of Long Sound that would indicate the continuation therein of this coastal bench, though it seems to be represented on the southern flanks of Treble Mountain by the sloping shelf upon which lie the lagoons shown in the map. The shelf is, however, vaguely defined and becomes visible from Preservation Inlet only when the illumination of the mountain slopes comes from an appropriate angle. It is well defined on the south-western spurs of Treble Mountain and is sharply distinct where interrupted by Southport and Preservation Inlet, though its landward limits are very indefinite, owing to the gentle slope of the mountain. It may be traced northwards along the eastern coast of Chalky Inlet, continuing with increasing elevation into the prominent spur above its junction with Cunaris Sound. No clear indication of remnants of this coastal bench can be seen along the sides of the upper part of Edwardson and Cunaris Sounds, though there are hints of it to the north-east of Northport, where a gently sloping mammilated bench averaging about a thousand feet in height above the sea appears to have resulted from the glacial scouring of the remnants of the Coastal Plateau to a depth of several hundred feet. The western slopes of the Brothers and the Kakapo Mountains slope gradually down into the Coastal Plateau to the north of Cape Providence, and it is apparent from the topographic map of Dusky Sound that the change of slope is fairly abrupt at the base of Mount Bradshaw, and is continued by the western slopes of Resolution Island, the low Five Fingers Peninsula being also a portion of the Coastal Plateau. The broken ridge constituted by Gulches Peninsula and Passage and Great Islands lies mostly below the summit level of the Coastal Plateau, but the outer seaward slopes of Chalky and Coal Islands continue its level from north of Cape Providence to the south-east of Puysegur Point (Plate 3 D; and Map, Text-fig. 4).

Hypotheses of Origin.

The Coastal Plateau may conceivably have originated in one of several ways.

Hypothesis No. 1.—Andrews (1911) was of the opinion that it represents the downwarped continuation of the Fiordland Peneplain.

* A notable instance is the "Knob" near the head of the Wilson River, a rocky peak rising abruptly over 100 feet above the general plateau level. (See distant view, centre of Plate 3 A.)

Thus he says, " Earth forces raised *a* peneplain here in recent times to form *two* high plateaus." The grounds for this conclusion are comprised within the following sentences taken from the same paper. " Whenever two peneplain or old age surfaces are found associated in resistant rock structures . . . and the two such surfaces are situated the one above the other, and the two are separated by a youthful or mature topography, it may be considered that they were formerly continuous, but are now discontinuous, owing to earth processes other than those due to erosive activities. Such earth processes may be either warping or faulting."

In Andrew's view, therefore, the steep western rise in the profiles traced in Plate 2, D, E, would be the result of a pronounced local dislocation. That this view is inadequate seems probable for two reasons. The first is that the higher plateau has been so highly dissected that it is represented only by sharp-cut, narrow divides separated by huge valleys, but wide interfluves remain between the early mature or youthful valleys that traverse the lower plateau, even where it is cut in comparatively yielding Tertiary sediments. This absolute difference in degree of dissection is strong if not conclusive evidence that the two surfaces are not coëval. Secondly, the inner margin of the lower surface is strongly sinuous, for it enters for some distance into the major embayments of the upper surface; this makes difficult of acceptance the view that the two were separated merely by a line of warping.

Hypothesis No. 2.—A second possible explanation is that the Coastal Plateau resulted from partial peneplanation of a coastal strip of the Fiordland Peneplain consequent upon uplift and warping subsequent to its formation. Professor Speight has kindly drawn the writers' attention to Gilbert's (1904, pp. 129-134) account of low-level peneplains along a portion of the Alaskan shore-line which rise on their landward margin to a height of three or four hundred feet above the sea. They have been cut in relatively weak slates and mica-schists lying between the shore and more resistant granites and quartzites further inland, which form an older high-level plateau, from which mature valleys open out on the lower peneplains. The greater part of the Coastal Plateau near Preservation Inlet is considerably higher than the Alaskan low-level peneplain, and there is no relation between its limits and those of the various geological formations. Granites, as well as schists, slates, quartzites, and Tertiary sediments are in turn truncated by its surface. But though there is an abrupt rise from the Coastal Plateau to the level of the Fiordland Peneplain at the Bald Peaks and Mount Bradshaw (Plate 2 D), the long slightly concave slope rising from the plateau remnant above Southport up to the level of the Fiordland Peneplain in Treble Mountain may well have formed during a partial peneplanation such as Gilbert envisaged (Plate 43, Section; Plate 3 D; Plate 4).

Hypothesis No. 3.—The Coastal Plateau, though now uplifted, may be deemed comparable in origin with the strand-flats of Norway. The Fiordland Peneplain, it may be assumed, after elevation was

dissected by many small valleys, as well as the few large inlets, so that on partial submergence it had an exceedingly indented shoreline. At a time of considerable refrigeration, preceding, however, the last expansion of the ice, this very broken coast-line was so eroded by wave-action fortified by excessive frost-work that the many promontories and islets were consumed and a wide platform or strand-flat was produced. The detritus was washed into the valleys and fiords that traversed the area and was later removed from these by the normal marine, fluviatile, and glacial processes which were active during and after the subsequent uplift.

The formation of fiords and the coastal dissection generally before the cutting of the strand-flat in this manner are strongly urged by several Norwegian writers such as Nansen (1922, pp. 46-7). Holtedahl (1927, pp. 146-167) believes that this process, though probably effective, is not always of dominant importance. He supposes instead that, after some marine planation, the low shelves thus formed may become covered with a coastal ice-sheet and broadened by the headward cutting of its feeding cirques. As the hemicycle of glaciation advanced to its maximum, continental glaciers descending the great fiord valleys would overflow the coastal lowland, plane its surface, and smooth away the minor irregularities left by the cirque-heads in its landward bounding slopes. Comparison between the Fiordland Coastal Plateau and the Norwegian strand-flat fails, however, in several respects. The maximum elevation of the former is about ten times that of the strand-flat described by Nansen, and, in place of being nearly horizontal, its surface slopes sometimes with increasing declivity seaward. It is not best developed near the mouths of the main inlets, but between them, and its planation cannot have been conditioned by the "preceding splitting up of the land-mass into peninsulas and islands," as is necessary for the Norwegian strand-flat. It might be held that the "hummocks" and "conical hills" are analogous to the cliffed islands which make the Norwegian "skjaergaard," but this cannot be discussed, as the writers were unable closely to examine the residuals in question.

The absence or obliteration of anything corresponding to a sea-cliff on the landward side of the plateau and its deep dissection by extended and consequent streams do not accord at all well with the idea of the origin of the surface in glacial times in the manner described, nor does there seem in Nansen's and Holtedahl's accounts to be any Norwegian analogy for the merging of the coastal platform into several flights of terraces, prominent on its seaward face as well as on the sides of the valleys, such as seem to occur near Big River (but of these only distant views were obtained).

Hypothesis No. 4.—The Coastal Plateau may be an uplifted surface which has had a twofold origin. It may be supposed that after a moderate elevation of the Fiordland Peneplain a low partially planed surface was produced subaërially in the manner described by Gilbert (See 2 above). Slow subsidence then permitted the sea to transgress across it, and to plane the gently undulating surface truncating alike the Tertiary and Ordovician sediments and the

granites, a process which must have been slow enough to permit the obliteration of nearly all traces of the small coastal cliffs that were formed. The "hummocks" and "conical hills" may then represent wave-cliffed residuals of the higher portions of this lowland which formed off-shore islets at the time of greatest submergence when the Fiordland Peneplain had been lowered to within two thousand feet of sea-level (See middle of Plate 3 A). Coastal detritus and river-alluvium accumulated in the drowned river valleys or was exported seawards. Then re-elevation of such character occurred that the wave-cut surface was raised to form the present Coastal Plateau rising from near modern sea level to a height of over fifteen hundred feet. It was more or less completely stripped of its cover of unconsolidated detritus as it rose through the littoral zone, and, in consequence of irregular rate of uplift, under favourable conditions developed terraces which modified its even slope. Streams that had extended across this plateau from the adjoining former coast and the new consequent streams cut deep canyons, with re-excavation of old valleys buried under unconsolidated detritus, this process being aided by the betrunking of the streams as the sea-cliffs receded before the attacking waves. Even the huge accumulations of detritus in the valleys of the former major streams were removed, and, thus rejuvenated, these latter proceeded further in the adjustment of their headwaters to the structures that they traversed.

Later, as the climate changed, glaciers advanced down the main valleys, scouring them out to their present depths, which are very great within the narrow parts of the valleys, though not so great near their mouths, where the flow, diminished by melting and ablation, deployed over wider channels. Within the region of maximum glaciation erosion upon the valley-sides removed the last remnants of the pre-glacial high-level bench. Thus, it may be supposed, there were developed the raised Coastal Plateau, the deep sounds, and broad shallow inlets.

So far as it refers to the effects of glaciation, the hypothesis accords more or less with Andrews' earlier views (1905; 1906) and gives, moreover, a hint as to the origin of the "double slope," to which he directed attention as occurring in many of the New Zealand Sounds (Andrews 1906) and which may represent residuals of the high-level bench.

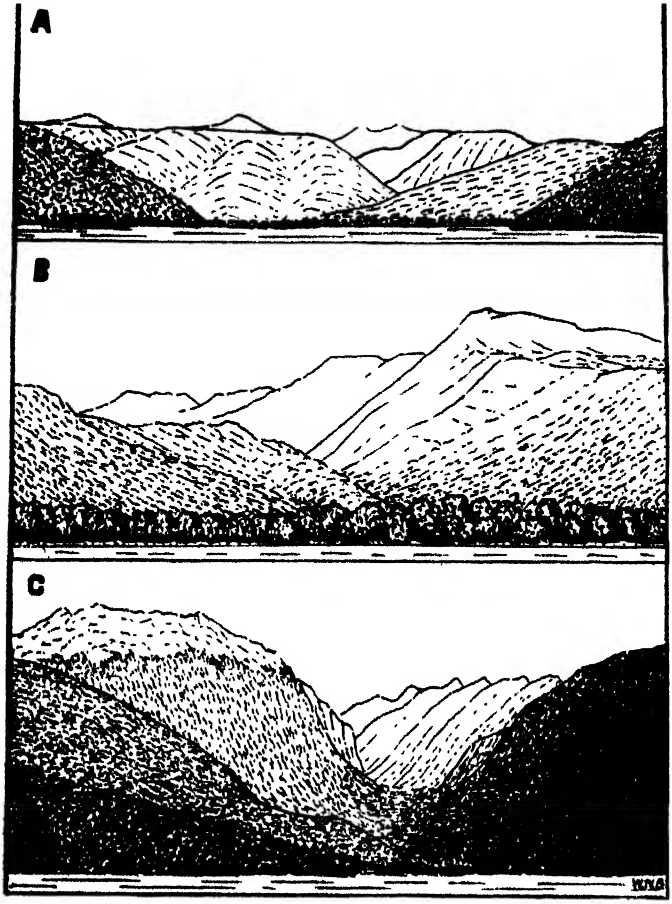
On either side of the outlets of the major valleys the Coastal Plateau was covered by a thin piedmont ice-sheet, creeping slowly seaward and depositing ground moraine and outwash-gravels. These would temporarily protect the plateau from dissection by rivers, though such erosion would become active again as soon as the ice retreated.

The assumption that débris-filled valleys were completely scoured out after the Coastal Plateau had been elevated suggests that some valleys might occur in which this process was not carried to completion. An instance appears to be afforded by the Cascade Valley, two hundred miles further north. According to Turner (1930a), the valley was cut along a fault-zone in the Fiordland Peneplain,

and, during a period of subsidence, became partly filled by coarse gravel which spread out into a broad delta-fan. Uplift followed to such an extent that the landward margin of the fan was raised to 1800 feet above the sea. The gravel, however, had become strongly cemented. The revived Cascade River cut a deep broad valley across only the southern flank of its former delta-fan. Though it has since been truncated by coastal recession, notched by consequent streams, and partly covered by a thin sheet of ice (an overflow from the Cascade Glacier), a broad quadrangular block of the delta-fan still remains to form the Cascade Plateau, and residual masses of the cemented gravel, resting on the sides of the Cascade Valley, extend for some miles upstream.

It is not yet clear what evidence exists for the continuation of the Coastal Plateau between Cascade River and Dusky Sound. Park (1887) spoke of terraces from 100 to 300 feet high extending southwards to Martin's Bay, and, according to the verbal statements of Mr E. James, a strip of relatively low land runs between the high mountains and the coast almost as far south as Milford Sound. Yates Point, five miles north of the entrance to Milford Sound, as noted by one of us (Benson), has a form very suggestive of the existence there of a feature comparable with the Coastal Plateau (See Text-fig. 5). Further south, Hutton (1875, p. 80) noted a series of narrow terraces on either side of the entrance to Doubtful Sound, the highest being at an elevation of about 800 feet.

The degree of maturity attained in the main Preservation and Chalky valleys after the uplift of the plateau, but prior to the glaciation, demands attention. The existence at the present time of remnants of the Coastal Plateau level, represented by the benches on the slopes high above the entrances to Long, Cunaris, and Edwardson Sounds, and the rarity of small tributaries deeply incised into the sides of the Sounds, shows that the tributaries could not have been developed to such an extent that their dividing ridges survived the lateral scouring-action of the great glaciers. The major tributary valleys, namely, Richard Burn and Lumaluma Creek, which were clearly important prior to the uplift, were thereafter deepened by subaërial and glacial erosion to an extent almost comparable with the development of the main valleys. Between the extremes furnished by the small tributaries and these last are several streams draining catchment areas of moderate size each containing portions of the marginal slope of the Fiordland Peneplain and of the Coastal Plateau at its foot. In all instances the general course of the stream runs a little south of west parallel to a series of joints and fractures; valley-development may consequently have been favoured, even though the rock traversed is granite in all but one case. The upper portions of the valleys of Blacklock Stream and Dawson Burn, the only two which have been observed by us, have obviously been glaciated. Blacklock Stream, with a catchment of five square miles, has had its lower portion so cut back that it now hangs several hundred feet above Long Sound. The adjacent valley of Dawson Burn (See Text-fig. 6 B), with a catchment of ten square



TEXT-FIGURE 6.—Views of three valleys cut in granite.

A. Valley of Gray River seen from off Kisbee Beach: a pre-glacial valley cutting a V-gorge 1400 feet deep through the edge of the Coastal Plateau and draining about eight square miles of westward-facing catchment. Bald Peaks (3500 feet) in background. Ice coming south from Revolver Bay (behind the hill in the left) divided above the low ground in the middle distance, part of it flowing towards the observer into Preservation Inlet, and part continuing southwards, rising on to the Coastal Plateau, and depositing thick masses of moraine on the slopes rising to the right.

B. Valley of Dawson Burn entering the southern end of Long Sound, draining from Caton Peak (3784 feet) with a westward-facing catchment of 10 square miles. Glacially modified in its upper portion; an open V-gorge in the lower portion. Remnant of Coastal Plateau on right. Main ice-flow from left to right. Traced from photograph.

C. Unnamed valley entering Edwardson Sound near its head. Eastward sloping catchment of about four square miles area, rising behind Inaccessible Peak (3600 feet). Main ice-flow from right to left. Traced from photograph.

miles, is so much more deeply recessed that its enclosing spurs have escaped complete truncation even though the valley opened on to the convex side of a right-angle bend in the course of the main ice stream. The same may be remarked concerning the Gray River valley (See Text-fig. 6 A), which has a catchment of eight square miles and enters the south-eastern angle of the Preservation Inlet depression through an open gorge cut to a depth of over 1400 feet in the edge of the Coastal Plateau In both these cases the lower valleys are V-shaped, show little or no sign of glacial modification and appear to have been formed subaërially and adjusted to a base-level rather below the present sea-level * At the time of their formation, therefore, the floor of the main valley, now occupied by Long Sound, must have been excavated to a depth below the present sea-level at least as far from the coast as the mouth of Dawson Burn, and, thereafter the crust movements amounted in all to moderate subsidence. The increasing body of evidence that in New Zealand, as well as in other countries, there was more than one epoch of Pleistocene glaciation (cf. Willis 1932) raises the question as to whether such a deepening of the main Long Sound valley was accomplished in pre-glacial times, or whether it could have resulted in part from the excavation performed during an early epoch of the glaciation. This involves the decision as to whether such deep gorges could be cut in inter-glacial times. On the views of Garwood (1910; 1932) this might be affirmed, and attention might be drawn to the contrast between the forms of these westward-facing tributary valleys and that of the small glaciated valley discharging eastward into Edwardson Sound near its head (Text-fig. 6 C). It is difficult to obtain quantitative conceptions from the available literature, but though a considerable amount of subaërial gorge-cutting in riegels and valley-steps and benches during inter-glacial times is recognised by Penck and Brückner (1909), De Martonne (1910-11), Nussbaum (1910) and others, there is little to indicate in the works cited that streams with such small catchments as the Gray and Dawson could excavate in granites such large valleys during inter-glacial times.† Moreover, the even slopes of the sides of these valleys lend no support to an hypothesis of multicycle origin.

The extent of development of Kohe Creek is even greater than that of these other streams. Possessing a catchment of eight square miles, this stream rises on the west of Treble Mountain. It is not

* Gilbert (1904, pp. 151-6) describes V-shaped valleys slightly modified by ice and more or less truncated at their mouths entering the upper portions of the Lynn Canal almost at grade and concludes that "there was a pre-glacial, comparatively narrow valley through the Lynn Canal, the floor of the valley being below present sea-level. Lateral V-gorges were tributary to it, and were largely adjusted to it at grade. The Pleistocene glacier broadened the river valley, truncated the side spurs and the tributary gorges, and at the same time materially deepened the valley for the whole breadth of the trough." Capps (1931) holds that here "faulting had much to do with the establishment of the pre-glacial drainage lines."

† Atwood and Mather (1932, pp. 58-9, Plate 17 C) described the gorge of a large stream which has been cut into schist and granite to a depth of about 2000 feet since the earliest Pleistocene glaciation.

noticeably glaciated in its upper portions and is deeply incised into the gently sloping flanks of this mountain and into the Coastal Plateau, whilst it enters Southport in a widely open early mature valley which has received a number of tributaries apparently entering it at grade A flat delta extends a short distance into its valley. It also must be considered to have been formed in pre-glacial times adjusted to a sea-level rather lower than at present existing.

The absence of deep valleys dissecting the southern slopes of Treble Mountain indicates that during the same time the tributaries of the main valley through the Preservation Inlet area can have had only short valleys dissecting the surface of the Coastal Plateau and adjusted to the shatter-zones of which Isthmus Sound, with Revolver and Useless Bays may be the evidence. These valleys did not extend back into the higher slopes of Treble Mountain. Gray River possibly found an outlet at this time through a valley ancestral to Otago's Retreat, though the fact that it was adjusted to the same base-level as Dawson Burn, which entered a much more powerful stream, renders this unlikely. The seaward slope of the Coastal Plateau is sufficient reason for the lack of noteworthy northward-flowing tributaries.

Similar tributaries to the main Chalky Valley may have been developed along fracture-zones in the neighbourhood of Northport, but were not incised to any great extent in the flanks of the Kakapo Range, say, near Mount Inaccessible (Text-fig. 6 C) Traces of the old plateau level appear as a glacially scoured bench extending a couple of miles north-east of Northport, while on the eastern side of the Inlet the Coastal Plateau, which is well developed south of Kohe Creek, passes northwards into a faintly-marked bench above the mouth of Cunaris Sound. It is noteworthy that whether or not the eastern opening of Chalky Inlet was in existence in pre-glacial times, the pre-glacial maturing of Kohe Creek betokens a pre-glacial origin for the Southport depression, though not necessarily the existence of an outlet valley there

Hypothesis No. 4, now under discussion, thus leads to the conclusion that at the commencement of glacial times sea-level stood rather lower than at present. The main streams, and a few of their tributaries draining remnants of the Fiordland Peneplain and rejuvenated by the uplift of the Coastal Plateau, had cut deep valleys extending far up their courses, but their minor tributaries had formed only short youthful gorges, dissecting their old valley floors and guided largely by fracture zones, and had seldom become recessed into the higher slopes. They had, however, cleared out most of the detritus that had accumulated in their former valleys. It follows, however, that the plexus of small gorges formed in the Preservation Inlet area must have taken a large share in the total excavation that had been accomplished in that area.* Accordingly, when the glaciers advanced down the main valleys and spread over

* Apart from a moderate degree of glacial modification the present features of Kiwi Burn Valley (see Plate 2 A), especially in its lower portion, afford a small-scale analogy with the inferred form of the Preservation Valley immediately prior to glaciation.

the Coastal Plateau, they occupied in the latter not only their main outlet channels, but also a plexus of small valleys which greatly facilitated the work of erosion.

On the assumption that erosion is competent completely to account for the present land forms, it should first be observed that the glacier discharging from Long Sound rose high above the level of the remnants of the Coastal Plateau. The scoured form of the promontory by Arnett's Peak, and of the plateau remnant above the mouth of Dawson Burn, and the broad channel of high-level flow from the end of Long Sound into the Gray River catchment which McKay had seen, afford evidence of this. There would consequently have been a vigorous discharge into the Isthmus, Useless, and Revolver valleys cutting down the divides at their heads, so that in the case of the last the ice crossed the divide to reinforce the flow in the Gray River valley. As the ice advanced thus on to the dissected coastal plateau with its greatest force concentrated at three points, conditions were propitious for the development of a wide terminal basin, even though the glacier became considerable deployed. Excavation was further facilitated by the fact that the formations on to which the glaciers emerged from the rather sparsely jointed granites were the abundantly jointed Ordovician quartzites and argillites, more susceptible to glacial plucking than any other formation in the region. It is significant that the eastern boundary of the depression occupied by Preservation Inlet almost coincides with that of the sedimentary rocks, while its southern shore, and its northern possibly, coincide with the heads of the small pre-glacial insequent gorges, for there are no important recesses made by large tributaries streams crossing these boundaries. The channels in the floor of the inlet follow the lines that might have been expected for the outlet streams, so that the various islands may be considered to be incompletely consumed resistant residuals of the former secondary divides. They consist chiefly of massive quartzite rather than argillite. Their small size compared with the granitic isthmus to the east betokens the greater resistance to glacial plucking and scouring offered by the latter.

The features of Otago's Retreat need special consideration. It is enclosed between steep almost rectilinear walls truncating obliquely the strike of the Ordovician and Tertiary sediments. Great bluffs of quartzite project from the eastern wall near the middle and at the northern end of the channel, and these bands of resistant rock are continued into Coal and Crayfish Islands. In a shallow recess between them lies Te Oneroa Beach, in which the rocks are largely argillites as at the Morning Star Mine. Immediately opposite this is the deepest part of the inlet, but the depth decreases rapidly near the quartzite bar on the southern side. The channel narrows seaward, and is half closed by a promontory composed of Tertiary arkosic sandstone. That the top of this promontory is the same height as the coastal plateau on either side of the channel seems to indicate that it has not been over-ridden by any effectively eroding mass of ice.

Certainly, the widespread morainic matter on the plateau on either side of Otago's Retreat may indicate a temporary extension of the ice-sheet over it, but the presence thereon of more or less stratified gravels shows that the conditions were often those of an outwash apron. Holtedahl (1929, p. 141) comments: "If there is any tendency for the ice to dig deeper in one sort of rock than another . . . conditions do not at any rate point in favour of the looser rocks; one would rather say that hard but jointed rocks give a more angular and complicated design to a fiord . . . so there is a greater chance of getting in these rocks an uneven irregular profile with very great depth. Evidently the plucking effect of a glacier is of paramount importance." Matthes (1930, pp. 89-103) also emphasises (and, according to von Englen, 1933, pp. 590-592, possibly over-emphasises) the importance of close-spaced jointing for the promotion of glacial erosion.* Matthes holds that in the Yosemite region cross-walls, glacier-stairways, and roches moutonnées are all the products of selective glacial erosion at points where monolithic, hence obdurate, granite masses are interposed between much jointed, hence quarriable, rock Hence in our region there is no reason to suppose that a relatively thin sheet of ice over-flowing from the main mass in Otago's Retreat should have on the Tertiary sediments as strong an effect as the thicker mass had on the harder but more jointed Ordovician sediments. At the same time, the seaward constriction of the "Retreat" suggests that it may have been formed by a lobe of the main glacier in the Inlet which had overflowed through a low saddle at the head of a small consequent stream traversing the seaward slope of the Coastal Plateau. The valley of this stream, possibly, was the outlet of Gray River at some stage of its history. The glacial lobe scoured out a small terminal basin, and did not extend beyond the promontory. As the tidal Big River fifteen miles east of the "Retreat" discharges from Lake Hakapoua through a valley cut in Tertiary sediments, so it may be that there was never any discharge of ice from the Inlet into the sea through Otago's Retreat. If this were so, the present opening of the latter would have to be explained by river-erosion and cliff-recession under wave-attack, together with some regional subsidence. Any terminal moraine must then have been removed in the formation of the outwash apron. Alternatively, it may be suggested that a terminal basin may have been formed by an ice-lobe in an early glacial period, the opening into the sea being made in the manner mentioned, but during an interglacial period, and enlarged by ice-action during a later glacial epoch. There is no need, however, for such an hypothesis. The small notch at the base of the promontory through which the lighthouse road has been made could easily have been cut by a small stream escaping from the ice-front.

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* In Yosemite this holds within a single lithological unit. "Where the rock (granite) is massive or only sparsely divided by fractures, the glacier . . . can reduce it only by abrasion, a slow and relatively feeble process; on the other hand, where the rock is abundantly divided by natural partings the glacier will quarry out entire blocks and excavate at a relative rapid rate." (Matthes 1930.) The writers have not yet had access to Ljunger's (1930) paper on the morphological significance of fractures.

If either of these views as to the origin of Otago's Retreat be accepted, the implied wasting away of the main Long Sound ice so near the coast may explain the failure of the main ice-stream in the Inlet to broaden the opening between the resistant masses of Crayfish Island and Cavern Head, though there is no reason to doubt that there was a considerable discharge of ice into the sea through it.

Hypothesis No. 5.—Though the hypothesis last discussed seems adequate to explain the present topography of the region, it is desirable to consider Andrews' (1911) final conclusion concerning the region: "The earth forces raised a peneplain here in recent times . . . and dropped a centre block to form the (Preservation) Inlet which has since been modified by glacial erosion." At one stage in these studies this view seemed to the writers to be inescapable. The narrow rectilinear channel of Otago's Retreat, half-closed by a promontory of weak rocks, and parallel to well-known lines of fracturing and perhaps faulting (the hypothetical fault along the west coast of Fiordland), seemed best explained as the result of trough-faulting, though the need to suppose that the fault-strip did not extend the whole length, but left a "bridge," subsequently reduced by erosion, at the southern end, imports a special feature which, though not fatal, lessens the probability of this hypothesis. Again, the rectilinearity of the boundaries of Preservation Inlet itself and in particular of the long wall extending from Revolver Bay southwards, together with the need of explaining the early development of a base below the present sea-level to which the Gray and Dawson valleys could become adjusted before the glacial period, offers support for the hypothesis that this broad depression resulted in part from a pre-glacial subsidence of fractured crust-blocks, such as has occurred on a large scale in many of the intermontane basins of the South Island of New Zealand. It still remains possible that such movements may have been instrumental in the dismemberment of the coastal plateau in pre-glacial times, but the features of Preservation Inlet alone seem inconclusive as evidence of recent subsidence of this character.

Further, the western side of Southport coincides with the most strongly marked fault in the district studied, and in topographic form is either a fault-scarp or fault-line-scarp. The eastern side has a much gentler slope, and north of the mouth of Kohe Creek rises gradually up to the level of the Coastal Plateau. The section (Part I, Plate 43) suggests this may indicate the stripping away of Tertiary rocks involved in a fault-angle depression during the pre-glacial dissection of the Coastal Plateau. If such a fault continued across to join the fracture-zone along the western shore of Edwardson Sound (thus outlining the granite massif), it is conceivable that for a time the outlet of the Chalky drainage may have been through here. This suggestion need not assume any dislocation of the Coastal Plateau, but an explanation of the maturity of Kohe Creek involving the pre-glacial subsidence of narrow crust-blocks in Southport and Chalky Inlet would require such movements. Once more, however, the evidence is inconclusive.

The glacier in Chalky Inlet had probably a greater catchment than that in Long Sound (though the exact position of the divide between them is yet unknown). Moreover, it received by the through valley at Last Cove about a third of the total stream of ice moving down Long Sound (estimated by a comparison of approximate cross-sections), and there is such abundant proof of intense glacial scouring as far down as the junction of Edwardson and Cunaris Sounds that the overdeepening of these Sounds requires no further explanation. Overflow into a valley draining the Coastal Plateau between Chalky Island and Gulches Head, and its subsequent enlargement would seem a sufficient explanation of the eastern outlet of Chalky Sound, even if the main pre-glacial stream discharged through Southport (which need not have been the case). The glacial enlargement of Southport to its present form (Plate 3 F) would, however, follow only if there were maintained a significant difference of surface-levels between the Chalky and Preservation glaciers, which the abundant opportunity for westward discharge of the former would tend to prevent, though McKay cites evidence of a noteworthy flow of ice through this opening at one stage. If his description of the locality be correctly interpreted, the edge of the Coastal Plateau nearest to the Seek Cove-Southport neck bears a covering of morainic matter, indicating that the thickness of the ice here was for a time over 1500 feet.

There is sufficient analogy between the conditions in Preservation Inlet and those which must have obtained in the western part of Chalky Inlet to render it unnecessary to assume extensive block-faulting for the explanation of this western depression. Though there was here some deploying of the wasting glacier, three main streams must have come through Northport, Return Passage, and Bad Passage respectively, in each case through channels developed in granitic rocks. They passed out on to an area of normal, well jointed Ordovician sediments lying between Cape Providence and Chalky Island, which would have been very susceptible to plucking. The total volume of rock that was removed would have been comparable with that excavated from Preservation Inlet. The retention of a remnant of the Tertiary rocks now forming Chalky Island may be explained by Holtedahl's (1929) comment cited above.

General Conclusion.—The amount of topographical and geological detail available in this region of varied features has invited an attempt to make a fairly comprehensive application of the method of multiple working hypotheses to the elucidation of its geomorphogeny, in the light of the latest accessible discussions of the origin of the Norwegian fiords and American glacial topography. It has lead to the conclusion that in general the glacial excavation of a series of pre-glacial valleys adjusted to a more or less fractured series of diversified rock formations, together with small submergence of the region, is competent to account for the bulk of the features observed. And, further, though there are a number of facts suggesting that the differential subsidence of relatively small fractured crust-blocks may have influenced the pre-glacial relief, the evidence that this was the

case is not complete. Nevertheless, there is considerable probability that a major fault-plane determining the west coast of Fiordland obliquely truncates the coastal plateau in the region of Dusky Sound (See Part I, Text-fig. 2).

The Pleistocene Glaciation.

Distribution and Erosive Activities of the Glaciers.

McKay's detailed account of this period here and the above discussion need but little supplementing. During its maximum the ice must have risen to a height of over two thousand feet above present sea-level in the regions about the heads of Long, Cunaris, and Edwardson Sounds, whence it diminished westward to a thickness that just enabled it to overflow on to the Coastal Plateau as a thin sheet extending for some miles on either side of the main glacier-streams. The following particulars concerning the individual streams are noteworthy. The main Longburn glacier entered Long Sound over a riegel north of Houseroof Hill (Plate 3 E), on the north side of which it scooped out an overdeepened lake-basin. It was joined by a tributary glacier moving down Richard Burn, and continuing down the valley scoured and plucked the rocks to a depth of over fifty fathoms below modern sea-level, leaving sides of the valley shorn smooth save for a few truncated spur remnants. High plunging cliffs with gentler upper slopes mark the granite areas; more even and smoothed but less steep slopes (about 27°) occur on the mica schists. About a third of the ice overflowed through the gap from Last Cove to Cunaris Sound, the sides of which are intensely shorn and the base reduced almost to sea-level. The main flow, however, discharged over and through a granite barrier, dividing into several channels, and enlarging pre-glacial valleys that were probably controlled by fractures. The most direct flow passed over Jane Cove to Isthmus Sound, and a smaller one over a low col into Useless Bay. The chief flow meanwhile was deflected twice at right angles and passed through Narrow Bend, shearing off the lower portion of Blacklock Valley, which thus hangs above the Sound.

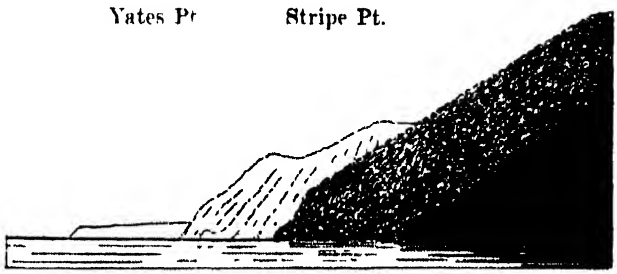
The lower portion of Dawson Burn Valley was protected, owing to its recessed situation at a bend of the main glacier, and was little modified by the ice, though the upper part was glaciated in common with that of Blacklock Stream. A thick sheet of ice flowed over the edge of the Coastal Plateau above Revolver Bay and, merged with the stronger stream that followed this latter depression, thrust against the south-eastern angle of the Preservation Inlet depression, though a thin apron extended over the plateau towards Wilson River. The main underflow, however, deflected westwards, scoured the southern wall of the depression, and entered Otago's Retreat. As in similar cases, there was but little modification of the Gray River Gorge, which was protected by its situation in a recess. The channels of the principal ice-streams outflowing across the floor of Preservation Inlet are clearly indicated by the bathymetric contour lines; between them there rise island-capped ridges.

TEXT-FIGURE 4.—Topographic and bathymetric map of Preservation and Chalky Inlets based on the Admiralty and Lands and Survey charts for coastline, depths, and spot elevations, and on numerous photographs and sketches as regards the form-lines, which are therefore approximations only. Numerous depths in Isthmus and Long Sounds are recorded merely as exceeding 54 fathoms; probably much of Long Sound is more than 100 fathoms deep.

The Cunaris Glacier, fed by ice from Carrick River, was thrust to the north by the ice, already noted, coming through the gap from Long Sound, which caused the coastal slopes that received the thrust to be recessed and ice shorn (See Text-fig. 4). For a short time there was probably some southward flow of ice from Edwardson Sound moving across the smoothed col between Tower Hills and The Lump. The southward direction of the ice sweeping out of the recess is proved by the striation of the promontory at its western end. The Sound itself was scoured to a depth of more than 130 fathoms, and a narrow channel was cut almost against Divide Head. Beyond the shelter of this spur, on receiving the full thrust of the Edwardson ice, the Cunaris ice cut off more than a mile from the end of a southern

promontory enclosing Cunaris Sound, the intensely plucked and abraded Cunaris Islands and the broad shallow submerged platform to the south of them remaining as residuals of this former spur.

The Edwardson Glacier received its main supply from the Oho Valley, in which Carrick (1895) noted a series of lakes* above the large Freshwater Lake, which is shown on the Admiralty chart and lies 80 feet above sea-level, so that the ice probably descended over a succession of rock basins and low riegels. It scoured out a broad hummocky lowland, nearly a thousand acres in extent, between Saddle Hill and the Sound. The main western flow into the Sound came down Lumaluma Creek, a normally glaciated valley, but a minor tributary glacier descended from the northern end of the Kakapo Range in a valley, which recalls the familiar "text-book" diagram of staircase valleys with U-shaped cross sections (Text-fig. 6 C). Between the Stopper and Mount Inaccessible, a mile to the north-east of the former, there is a tarn-filled cirque which now discharges into the Sound by an unrecessed stream following a granite slope



TEXT-FIGURE 5.—View from the entrance to Milford Sound, looking towards Yates Point, five miles to the north, showing the presence there of a coastal plateau. Traced from a photograph.

which, as Hector noted, is for the most part inclined at an angle of 40° and continues beneath the water to a depth of over 100 fathoms. This south-east slope has been worn to a plane surface, with intensely scoured and striated minor irregularities, which passes here and there into plunging cliffs. Across the Sound the opposing slopes facing north-west have been cut in mica-hornfels and schists and are less steep. Pre-glacial valleys moderately recessed in these slopes have been almost planed away. Towards the southern end of the Kakapo Range the higher slopes are concave instead of convex and somewhat mammillated or terraced, apparently the result of glacial modification of an earlier bench associated in origin with the Coastal Plateau. Lakes Rimmer and Caesar are probably recessed in the landward margin of this bench. The scouring of this bench, which lies about three or four hundred feet below the height of the Coastal Plateau appropriate for this situation, must have been influenced by the thrust of the Cunaris Glacier. There must have been a

* Preston's (1920) map of Dusky Sound shows some of these and suggests that Carrick's sketch-map exaggerates their size.

vigorous westward flow across Northport, to which may be assigned the responsibility for the enlargement of the main channel and perhaps also of that of the parallel tributary valleys, which seem to have been developed in pre-glacial times along a shatter-zone. Great Island would have been overridden, for its surface is mammillated and bears two small lakes. The spreading of the ice through Return Channel and Bad Passage may also have been effective in the excavation of those straits, and Passage Island would probably also have been overridden. It is not so clear to what extent Chalky Island may have been overwhelmed; its covering of detritus, so far as it exists, may have been in part fluvio-glacial. Between this and Cape Providence there would doubtless have been a series of Ordovician sediments, which would have been exposed to erosion by ice moving on to it from Chalky Inlet through three channels cut in granite. To some extent, therefore, the conditions of Preservation Inlet may have been repeated, and the glacial excavation of the western portion of Chalky Inlet seems a reasonable hypothesis. The main flow from Chalky Inlet, however, discharged east of Chalky Island, scouring out a terminal basin which even adjacent to the northern end of Chalky Island is over fifty fathoms deeper than any recorded sounding in the open sea within a radius of five miles, and is probably considerably deeper nearer Northport.

The effects of the ice that descended westwards from Kakapo Range are scarcely known. Lake Hector seems to be in a rock-bound basin some 600 to 800 feet below the level of the Coastal Plateau, and discharges by a short stream at first broad and swampy, which, after passing the remnant of a terminal moraine, becomes narrower and steeper and falls in all about 200 feet into a valley, which turns sharply and discharges through a short gorge into the sea instead of following what would appear to be its natural route along a broad, gently-sloping through valley, which runs to the north-east almost parallel with Northport. Apparently there has been here considerable erosion along intersecting shatter-belts and perhaps subsequent glacial modification, but the details have not been determined. Lake Thomas also discharges by a stream which follows a mature valley in the plateau until it suddenly descends by a steep youthful gorge about 700 feet to Landing Bay.

The Glacial Deposits.

No special attention was paid to the glacial deposits by the present writers, and reference must be made to McKay's (1896) detailed account of them, which, however, seems to require modification in some respects. McKay found that they extended over the Coastal Plateau forming outlying patches, and that they cover three-quarters of the surface of Coal Island, the western margin of the plateau east of Southport and part of the peninsula to the west thereof, whilst he correctly inferred that they would also occur on the gentle slope from the Kakapo Range to the West Coast. Neither he nor the present writers, however, ascertained whether these deposits occur on Chalky Island. Clearly, they were formed beneath

a piedmont ice-sheet which overflowed from the main ice-streams on to the enclosing sloping plateau. On " the height of land " near the head of the Wilson River ". . . they reach an elevation of 950 feet. At places the glacier-drifts appear as deposited, but usually the upper portion has been modified, at higher levels but slightly, but in the middle and lower parts of the slope the material has been separated into coarse bouldery wash and beds of finer sand. Below these re-sorted drifts there is usually an unascertained thickness of unmodified glacier deposits, readily distinguished from the former by the angular character of the material and the presence of clayey material giving the lower deposit the appearance of a till. . . . Between the landing at Otago's Retreat and the Puysegur Point lighthouse there appears on the flat-topped spurs on each side of the road a very coarse but well-rounded gravel, and a small creek cutting through this has its bed choked by granite boulders of large size. This is, therefore, a glacier deposit, first re-assorted by the sea and afterwards cut through by the creek, so that the shingle in the creek is much concentrated, and, being auriferous, has, to a limited extent, been worked for gold " (McKay 1896). A like explanation is given of the concentration of gold in other valleys.

" The action of the sea " has been traced up to a height of 800 feet, but no other evidence than the rounding and re-assortment of the gravel is offered for the rise of the sea to this level. The alternative explanation that this re-assortment was the work of outwash streams descending the sloping plateau from the piedmont ice-sheet is supported by the presence of lignitic and swamp material on the flat-topped spur leading to Puysegur Point.* McKay held that on the southern slopes leading to Preservation Inlet between Kisbee Beach and Otago's Retreat, similar " evidences of marine action " are abundant. This can hardly be due to re-sorting of an outwash apron, but conceivably may be the work of streams at the margin of the glacier. Stratified drift on a shelf at an elevation of 150 to 200 feet behind Te Oneroa Beach (Berg's claim) contains masses of scarcely-lignified wood. At Price's Beach, east of Gulches Head, " the action of the sea breaking up and re-assorting the tough underlying boulder clay has led to the formation of about thirty feet of thick auriferous gravels " (McKay). These gravels form a terrace with a slight slope to the south and west, and, like the others, may possibly have been re-assorted by a stream marginal to the ice-sheet. On their flank there is a narrower lower terrace of fine auriferous black sand. (See Plate 3 F.)

The subsidence of the land and its subsequent rise to an amount of eight hundred feet since the end of the glacial period, as postulated by McKay, might be expected to have left many more indications of raised beaches than the few that have been noted. Doubt is,

* Comparison is suggested with the peaty shales, sands, and shingle of the outwash gravel forming the great terraces near Strahan in western Tasmania described by Sir Edgeworth David (1924) in a paper which may have considerable bearing on the history of Pleistocene glaciation in New Zealand.

therefore, felt concerning the correctness of this conclusion of McKay's, though indications of minor post-glacial movements of sea-level are noted in the next Section.

Among other glacial deposits worthy of note are "the vast accumulation of morainic matter" plastered against the hill-slopes east and south of Kisbee Beach as the ice retreated, and a large deposit of the same material recorded by McKay as laid down upon the spur above Southport Isthmus at the confluence of two glaciers. West of Kakapo Range fluvio-glacial gravels cap the cliffs near Cape Providence, forming a layer some ten feet in thickness and eighty feet above sea-level at the Cape, but rising to two hundred feet or more in elevation further north. The presence of "varve" rocks was noted *en passant* on the slope about 100 feet above the north-western angle of Landing Bay. They show a face about ten feet high of horizontal, rhythmically-banded silts, with layers from two to ten millimetres in thickness which probably represent seasonal deposits in a lakelet at the side of the receding ice-sheet. An arcuate ridge of boulders which crosses the adjacent bay marks probably a temporary marginal moraine.

McKay declares that there are no glacial deposits on the south-eastern slopes of Treble Mountain. Were this not so, it would be natural to consider that the "lagoons" there were held in glacial deposits on a remnant of the Coastal Plateau. As a further feature of the glacial deposits, mention may be made of erratics, often of huge size, which litter the shores of the Sounds and occur in profusion on all the islands in Preservation Inlet.

The huge thresholds at the entrance to Chalky and Preservation Inlets, though probably in large measure composed of solid rock, are also likely to be covered with massive terminal moraine, and wave-distributed material. The smaller inner threshold at the entrance to Isthmus and Long Sounds are more likely to consist mostly of terminal moraine marking a retreat-stage of the main glacier.

POST-GLACIAL FEATURES.

1. *Erosional Features.*

(a) Fluviatile Erosion:

As elsewhere in New Zealand, there has been little post-glacial stream erosion, as is indicated by the many unrecessed streams and waterfalls "flaunting their whitened waters" on the slopes leading down into the Sounds. A marked exception to this is a steep-walled gorge cut on the northern slope of Cunaris at the back of the great ice-shorn recess facing Cliff Cove (Part I, Plate 41). It may be that the stream occupying it is cutting through a thick mass of readily excavated morainic material plastered against the valley-wall. The great fall over which Longburn enters the head of Long Sound has receded two hundred yards or more into the face of a high riegel, which here crosses the valley (Plate 3 E), but this may very largely

have been the work of a sub-glacial stream or of inter-glacial stream-activities. Recession of the low falls at the outlet of Freshwater Lake into the head of Edwardson Sound is much less marked; Hector (1863) remarked upon the depth of the pool below the fall.

(b) Coastal Erosion:

Recession of the sea-cliffs of the region may have been in progress during, as well as after, glacial times. It is evident in the cliffing and removal of all traces of glacial scouring and striation from all portions of the shores within a few miles of the sea, though further within the Sounds these features abound. In the more exposed locations, sea-cliffs more than three hundred feet high occur, and reach nearly six hundred feet in height on the western coasts of Coal Island and especially of Chalky Island. The projection of the surface of the Coastal Plateau from Puysegur or Long Reef Points would intersect sea-level less than half a mile from the present shore, indicating that coastal recession has been limited to this distance, but reefs and skerries which extend out nearly a mile from Cape Providence suggest that wave attack has there been particularly active in the recent past.

2 *Constructional Features.*

(a) Terrestrial Slope Deposits:

These do not require special comment. Hector (1863) remarked on the abundance of frost-riven rock-fragments forming a talus on the lower slopes of the loftier and steeper hills.

(b) Deltas.

Longburn and Oho Creek as effluents of overdeepened rock basins bring no heavy detritus into the heads of the Sounds into which they flow. Carrick River makes a large delta at the head of Cunaris Sound, while Richard Burn and the stream opposite it have nearly filled the top of Long Sound. The lowest reaches of Lumaluma Creek entering Edwardson Sound are alluviated, and noteworthy deltas have been built by a stream a mile to the south of the last-mentioned creek by Kohe Creek and by Dawson Burn. Gray River may have discharged at one time into Kisbee Bay, but, after building a broad flat largely from re-sorted morainic material, now discharges into Revolver Bay. Here it may be recalled that Hector (1863) emphasised how steep was the outer slope of the smallest deltas within the Sounds This is certainly true of the Gray River delta.

(c) Wave-deposited Material:

Examples include:—

1. The filling of Northport by sand coming in through Blind Entrance and choking the mouth of Shallow River.
2. The tombolos represented by the isthmus at Southport and Te Whara Spit, the beach behind this latter, and many small pocket beaches.

3. Redistributed detritus worn from the outer sea-cliffs and from moraine naturally occurs in huge amounts; its extent may be judged partly by the fairly even slope of the sea floor indicated by the few soundings. In sheltered waters sand continues to accumulate. Thus Otago's Retreat has a sandy floor and is crossed by a bar only a fathom deep, whilst the relatively shallow thresholds of Preservation and Chalky Inlets probably are partly built of wave-borne detritus. In more exposed portions of the coast, where the longshore currents are rapid, the finer material has been removed to a considerable depth, for a rocky bottom occurs down to about twenty-five fathoms as far offshore as four miles west of Cape Providence. The Balleny Reefs and possibly Table Rock are perhaps the remains of moraine deposited between the Chalky and Preservation Glaciers.

3. *Features Indicating Minor Oscillations of Sea-level.*

(a) Subsidence:

In addition to the already-described features of the Gray, Dawson, and Kohe valleys, which indicate that there has been a moderate subsidence of the region since the commencement of glacial times, the embayed character of the shores of Northport, Great and Passage Islands, and the fact that Wilson's River is tidal for a mile and a-half from the sea (Gordon 1893), and that Big River and Lake Hakapoua are also tidal, show that the evidence for such submergence extends throughout the whole area, though it is not yet possible to infer exactly whether the movement was in continuous progression or was limited to a definite period. The features about the mouth of Big River, where there seem to be a number of terraces visible from the sea, will probably be of most critical value in determining the precise history of glacial and post-glacial times in this district. Hutton (1875) was probably justified in rejecting as inconclusive other evidence of subsidence brought forward by Hector (1863).

(b) Elevation:

Hector (1863) noted on Crayfish Island a wave-cut cave, the floor of which was about ten feet above sea-level, and other caves elsewhere with floors up to twenty feet above the sea. From Cape Providence stretching towards West Cape there appears to be a narrow uplifted strand, at about the same elevation, at the base of the ancient sea-cliffs. Much of it consists of storm beach, but near the group of huge stacks three miles from Cape Providence, a raised rock-platform is also in evidence. In the sheltered parts of the Inlets, McKay recognised as raised beaches several other deposits, including the broad flat between Gray River and Kisbee Bay, a small beach at the north-eastern point of Coal Island, and another just east of Te Oneroa at Price's Beach, the isthmus at Southport, and the wide flat on either side of the mouth of Kohe Creek. In each case the surfaces are only a few feet above sea-level, and it is difficult

to be sure that uplift is actually indicated, since the level of the storm-beach of earlier times was certainly higher than that of to-day, when deposition has shallowed the near-shore waters in these bay-heads.

Higher terraces are indicated by a small cemented-gravel terrace at the north-east of Coal Island, which is exposed in a cliff about forty feet high, whilst McKay notes, but does not estimate, the height of gravel terraces on the east side of Southport. Hutton (1875) drew attention to a pierced rock at Green Islets, south-east of Preservation Inlet, which was surrounded by a wave-cut terrace forty feet above the sea. Finally, there are the higher terrace already mentioned between Price's Beach and Seek Cove, which present a cliffed margin nearly a hundred feet in height, and another small terrace of somewhere about the same height above Te Oneroa Beach. It has been suggested above that these were formed by streams at the margins of the glaciers. If so, they would have no necessary relation in elevation to each other. It is noteworthy, however, that in the case of the former, the streams draining from the central peak of Gulches Peninsula, now extended across the terrace, have been so rejuvenated by the disappearance of the ice or raising of the terrace that they have notched deep V-gorges in its seaward front (See Plate 3, Fig. F). As these gorges seem rather too large to have been cut in the massive Tertiary sediments in post-glacial times only (especially considering the amount of cliff recession that may have occurred), the suggestion may be advanced that they were developed during an inter-glacial period, and escaped subsequent obliteration, as the latest glacier was here almost at its termination, and in place of actively eroding its sides, was nearly stagnant.

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List and Descriptions of Illustrations accompanying Part II.

Plate 2.—Features of the Fiordland Peneplain and Coastal Plateau.

A. Panorama from the summit of Ben Lomond, Lake Wakatipu, traced from a series of photographs, showing the accordance of summit levels. Except for the narrow strip of infaulted Tertiary marine sediments shown in solid black, the whole region consists of more or less altered Palaeozoic (?) sediments, greywackes, and argillites to the west, semi-schists in middle distance, schists in foreground, north-west, and north. Geology after McKay (1880) and Park (1909).

B. Profile along S.W.-N.E. axis of Fiordland Peneplain.

C. Profile W.-E. across the gently arched Fiordland Peneplain showing the major departures from the general summit-level made by the elevated block of the Remarkables and the Cromwell depression (and Lake Wakatipu?); also the situation of the infaulted Tertiary marine beds.

D. Profile S.W.-N.E. from Windsor Point along the south eastern margin of the Long Sound catchment, the southern end of profile B. This is drawn in a thick black line. Against it are plotted three profiles (thin lines) running W.S.W.-E.N.E. adjacent to Dusky Sound based on Preston's topographic map (1929), and showing the continuity of the Fiordland Peneplain and the Coastal Plateau respectively in the two regions.

E. Profile from Windsor Point to Bald Peak showing geological structure. (After McKay, 1896).

F. Profile across the infaulted Tertiary sediments near Ben Lomond to natural scale, showing the hypothetical former position of the now-removed Tertiary sediments and its relation to the summit-level. Drawn to natural scale, and based with modifications on Park's section (1909).

Plate 3.—Sketches of coastal topography between West Cape and the Green Islets, N.W. and S.E. respectively of the entrances to Chalky and Preservation Inlets. Also views of the head of Long Sound and of the Solander Rocks.

Plate 4.—Preservation Inlet, taken from Morning Star Mine, Te Oneroa, Treble Mountain in the distance. (Bartrum photo.)

Text Figures.

Text-figure 4.—Topographic and bathymetric map of Preservation and Chalky Inlets based on the Admiralty and Lands and Survey charts for coastline, depths, and spot elevations, and on numerous photographs and sketches as regards the form-lines, which are therefore approximations only. Numerous depths in Isthmus and Long Sounds are recorded merely as exceeding 54 fathoms; probably much of Long Sound is more than 100 fathoms deep.

TEXT-FIGURE 5.—View from the entrance to Milford Sound, looking towards Yates Point, five miles to the north, showing the presence there of a coastal plateau. Traced from a photograph.

TEXT-FIGURE 6.—Views of three valleys cut in granite.

A. Valley of Gray River seen from off Kisbee Beach: a pre-glacial valley cutting a V-gorge 1400 feet deep through the edge of the Coastal Plateau and draining about eight square miles of westward-facing catchment. Bald Peaks (3500 feet) in background. Ice coming south from Revolver Bay (behind the hill in the left) divided above the low ground in the middle distance, part of it flowing towards the observer into Preservation Inlet, and part continuing southwards, rising on to the Coastal Plateau, and depositing thick masses of moraine on the slopes rising to the right.

B. Valley of Dawson Burn entering the southern end of Long Sound, draining from Caton Peak (3784 feet) with a westward-facing catchment of 10 square miles. Glacially modified in its upper portion; an open V-gorge in the lower portion. Remnant of Coastal Plateau on right. Main ice-flow from left to right. Traced from photograph.

C. Unnamed valley entering Edwardson Sound near its head. Eastward sloping catchment of about four squares miles area, rising behind Inaccessible Peak (3600 feet). Main ice-flow from right to left. Traced from photograph.

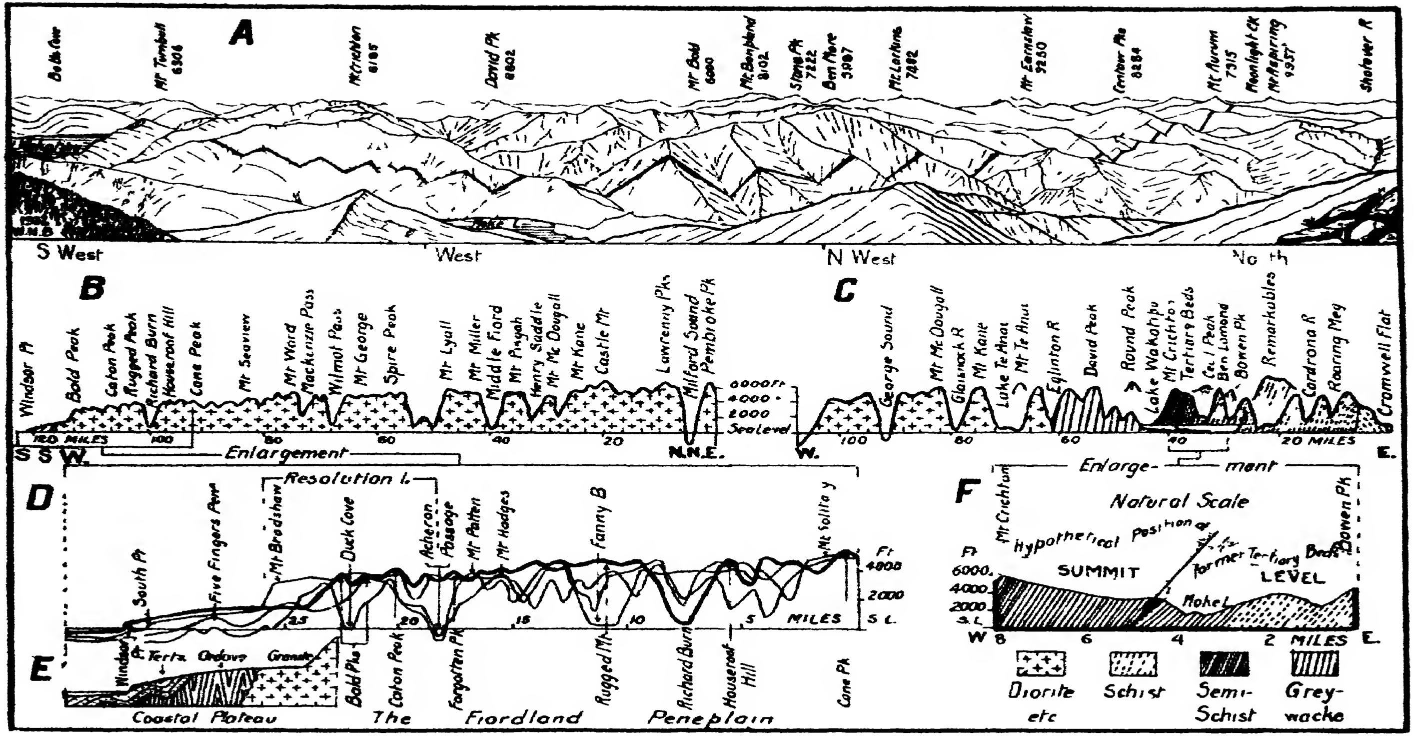


Fig. A.—Panorama traced from photographs taken from the summit of Ben Lomond (5747ft), showing position in solid black of fossiliferous Oligocene (?) marine sediments infaulted among the more or less altered Palaeozoic sediments which here rise to an accordant summit level the Fiordland Peneplain. Geology according to Park (1909).

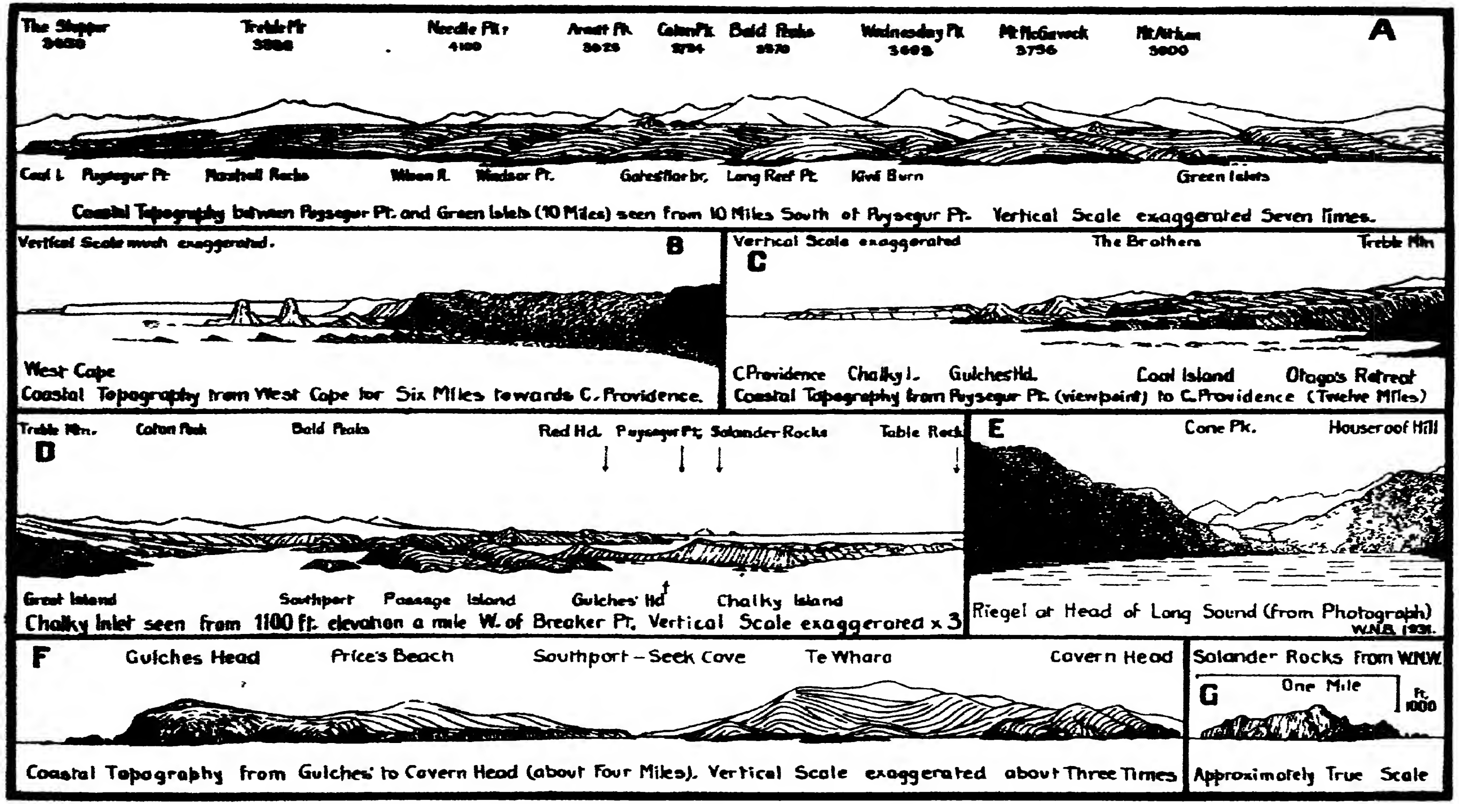
Fig. B.—Profile of the Fiordland Peneplain traced nearly along its axis descending from the head of Milford Sound southwards towards Preservation Inlet where it is cut off by the narrow Coastal Plateau.

Fig. C.—Profile across the Fiordland Peneplain showing its slight arching and the [illegible]

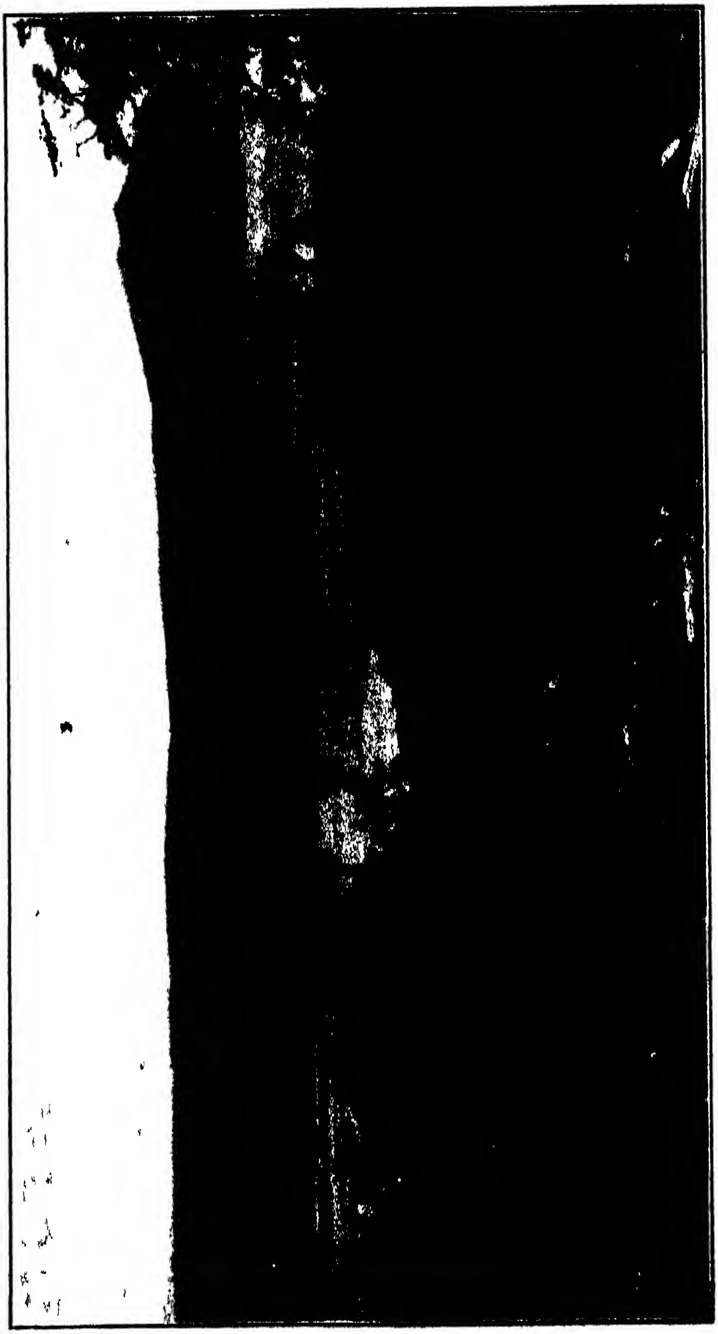
Fig. D.—Profile (in thick line) drawn along the south eastern crest bounding the watershed of Preservation Inlet and Long Sound plotted against three (thin lines) profiles W.S.W.–E.N.E. across the Dusky Sound area based on Preston's topographic map (1:29). Shows the continuity in all four profiles of the distinction between the Coastal Plateau and the Fiordland Peneplain.

Fig. E.—Geological Structure of the Coastal Plateau near Preservation Inlet.

Fig. F.—Section across the Moke Lake Valley near the view point of Fig. A showing [illegible] the infaulting of the [illegible]



Sketches of coastal topography between West Cape and the Green Islets, N.W. and S.E. respectively of the entrances to Chalky and Preservation Inlets. Also views of the head of Long Sound and of the Solander Rocks.



Preservation Inlet, taken from Morning Star Mine Te Oneroa Treble Mountain in the distance
(Bartrum photo)

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By the Royal Society of New Zealand Act, 1933,* the New Zealand Institute constituted by the New Zealand Institute Act, 1908, was abolished, and, with His Majesty's gracious approval, a body was constituted as successor to the New Zealand Institute to be called the Royal Society of New Zealand. The new Act is dated 6th December, 1933; from that date the name of the New Zealand Institute disappeared and the new title was adopted.

The Royal Society of New Zealand is now in possession of all the properties and has assumed all the responsibilities of the New Zealand Institute. All members and officers of the New Zealand Institute at 6th December, 1933, continue as members and officers of the Royal Society of New Zealand. Regulations, rules, resolutions, and orders became as effective under the Royal Society of New Zealand as they were under the New Zealand Institute, and all matters and proceedings begun under the New Zealand Institute may be continued, completed, and enforced by the Royal Society of New Zealand.

The Royal Society of New Zealand Act is a machinery measure for effecting a change of title. Under the New Zealand Institute Act, 1908, the Board of Governors was the corporate body; the Royal Society Act makes the Society the corporate body. The Act effects improvements in the method of conducting the affairs of the Society. The Governor-General becomes Patron instead of being a full member of the Board now called a Council. In the long title of the Act the words "a body for the promotion of science" revives an expression of purpose which was present in the Act of 1867 originally constituting the New Zealand Institute Act, but was omitted from later Acts dealing with the New Zealand Institute.

In other minor matters the Act gives that authority for doing what the New Zealand Institute has been in the habit of doing without authority. The Act specifies in detail the Society's power of making rules. Clause 11 repeats Section 7 of the Finance Act, 1925, stating the amount of the annual endowment from Parliament to be £500.

* Which will be printed later in the Volume.

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The Skeleton of a Small Moa, Emeus Huttoni Owen.

By Professor W. B. Benham, D.Sc., M.A., F.R.S., F.Z.S., F.N.Z.Inst., Hutton Medallist, University of Otago, New Zealand.

[*Read before the Otago Institute, November 14, 1933; received by the Editor, November 30, 1933; issued separately, September, 1934.*]

This account is founded on a practically complete skeleton of a female individual of this small species of Moa which was obtained by Mr David Teviotdale, preparator in the Ethnographic Department of the Otago University Museum, on December, 1929, on the sandy beach at Wakapatu, in Southland. He writes of its discovery as follows:—

> "While Mr A. King, of Orepuki, and myself were searching the Wakapatu Beach for Maori curios we found the skeleton of a small species of moa. It was lying in a compact heap with most of the bones in their proper position. I took no bones but those that were together. We found some fragments of egg shell among the bones. Wakapatu Beach is a dreary expanse of windblown sand, which is steadily advancing inland, killing the bush as it advances. The moa skeleton was lying just about where the outskirts of the bush would have been before the sand commenced shifting. I noticed scattered and broken portions of other skeletons lying at intervals in the neighbourhood; but I did not pay much attention to them—the majority were, I think, of a larger species than this one. I found no undoubted evidence of moas having been used for food in the middens here. A few days later, on the sandy beach on the Colac side of the Riverton rocks, I saw portions of moa skeletons also about the original margin of the bush."

Mr Teviotdale is an experienced observer, having for some years been accustomed to excavating Maori middens and other sites in the attempt to find the chronological order of the artifacts of the Maori.

The bones are those of a full-grown bird, the epiphyses of the leg bones being wholly ankylosed with the shafts; they are well preserved, though rather brittle, the sand having acted, as is usual, as a fine protector from decay. As egg shells were found among the bones, there is every reason to regard it as a female.

The skeleton is not quite complete, as it lacks the fourth cervical vertebra (if the number 21 is common to all species of moa as is usually believed); the pair of small free ribs belonging to the first cervico-thoracic vertebra; most of the phalanges, though the mid-toe of each foot is entire.

The skull is remarkably perfect, though the delicate bones of the palate and of the maxillary arch are missing.

The total height of the skeleton as set up is 1030 centimetres. But the height of any moa skeleton depends on the accuracy with which the taxidermist has articulated the vertebrae, on the curve

of the supporting iron rod, and also on the angle at which the femur is articulated with the pelvis, for sometimes it is set nearly horizontally, at others it is placed at a larger angle with the tibia.

Nomenclature of the Genus and Species.

Since the earlier and several of the later naturalists described the species from the measurements of the leg bones, and as these measurements are used by Oliver for diagnosing the genera in the first place, I commenced with these, and compared them with the various likely skeletons in the Museum collection. I found that the leg bones agreed well with those of a bird which had been labelled "*Anomalornis parvus*" But on looking up Owen's description of this species I saw at once that an error had been made in attributing our skeleton to it

But when the skull was studied, both that of the new find and of this old skeleton, I was led to identify them as Hutton's "*Mesopteryx didina* Owen," or, as it should now be called, *Meionornis huttoni* Owen As Oliver does not allow this generic name, I follow him in naming it *Emeus huttoni* Owen, although the name Meionornis is antecedent to Lydekker's definition of Emeus.

I here wish to pay a tribute to the patience and labour of Mr Oliver, who has summarised the various measurements of the leg bones as given by previous naturalists for the different species of the Dinornithidae He has converted the older "inches" into centimetres, and has tabulated the series of measurements so as to render it comparatively easy to identify the genera recognised by him, and for each genus he gives similar tables for the species. Although he is not at one with the various zoologists who have made a study of the moas as to the limits and names of the genera, yet he has rendered a useful service in thus bringing together in a convenient form the results of the earlier researches. His book will probably serve for many years as an authoritative guide to the study of the group. As there has been much overlapping of the genera by various authors in the past, owing to the fact that most of the earlier genera were founded on the character of the leg bones, some using the tibio-tarsus, others the tarso-metatarsus, and only a few correlating these with any certainty with the skulls, there has crept into the study a tremendous amount of confusion. It appears to me, therefore, desirable to follow Oliver, if only for the sake of peace, in this troubled realm of systematics. To begin overhauling the nomenclature and trying to find out what each author supposed to be the limits of the genera, as has been attempted by such competent men as Lydekker and Hutton, will be futile until we have complete skeletons of the various genera so that the skulls may be correlated correctly with the leg bones. Parker's excellent account of the skulls takes little or no account of leg bones, and in many cases he does not attempt to record the species, but calls them by some symbol.

It is a waste of time until we have such skeletons to commence the task of unravelling the tangled skein already much involved by Owen as well as by Hutton.

As descriptions of complete individual skeletons are few, it seems worth while to describe the present one in some detail. Owen described the skeleton of *Anomalopteryx parvus* in 1883, from a nearly complete skeleton; *A. oweni* was described by Haast in 1886, and Andrews gave a detailed account of *Megalapteryx didinus* (*tenuipes* Lydekker) in 1897.

HISTORY OF THE SPECIES.

EMEUS Lydekker, 1891 (nec Reichenbach).

Meionornis Haast, 1873.
Mesopteryx Hutton, 1892.

EMEUS HUTTONI (Owen).

Dinornis huttonii Owen.
Meionornis didiformis (part) Haast.
Anomalopteryx didiformis (part) Lydekker.
Anomalopteryx didina Lydekker.
Mesopteryx didina Hutton

In the early days, when anything like an entire skeleton was rarely met with, the species were characterised by the dimensions of the leg bones.

In 1868 Dr Julius Haast described and measured a number of these bones collected at Glenmark, in Canterbury, and among them were several which he allotted to *Dinornis didiformis* Owen, but he was able to sort these out into three groups according to size—" largest, middle sized, and smallest "—which he numbered 4, 5, and 6 in his list of species collected.

In 1874 Captain Hutton, then curator of the Otago University Museum, gave an account of the leg bones excavated from the Hamilton Swamp in Central Otago, and gives tables of their measurements. On p. 275 he writes:—

> " The bones that I have arranged under the name of *D. didiformis* belong probably to a new species. The tibia is well marked and quite distinct, but the femur and metatarsus that I have associated with it pass almost into *D. casuarinus.*"

This, by the way, indicates the " guess work " that almost necessarily occurred in these early days.

In 1879 Sir Richard Owen quotes on p. 430 the above words of Hutton, and comments: " Possibly the Dinornis of the South Island with the tibia characteristic of *D. didiformis* of the North Island may need to be noted as *D. huttonii.*"

In 1882 Owen gave an illustrated account of a head and neck and a leg and a foot of a bird with the dried skin and flesh wrapping round the bones. To this he gave the name *D. didina.*

In 1891, Hutton, in his article on "The Moas of New Zealand," enumerates the species of moa recognised up to that date. On p. 129 he names one of the species *Mesopteryx didinus*, and gives as synonyms Haast's numbers 5, 6 skeletons above mentioned, Owen's *D. huttonii*, and, further, Owen's *D. didinus.* On p. 130 he writes:—

> "Sir R. Owen gave the name *D. huttonii* to *this* species on the strength of my statement that it was different from *A. didiformis*, but without any description. Afterwards he described *it* under the name of *D. didinus*, and I think that the name that accompanied the description ought to take precedence."

No doubt it should if the two birds are the same. I have italicised the words "this" and "it," for the implication by Hutton is that Owen had had under his observation the same set of bones in both cases. There is, of course, no evidence that Owen ever saw the bones from Hamilton Swamp, while it is quite certain that Hutton had not seen the remains of *D. didinus.* Nor does Owen in his account of the latter species refer to his former suggestion about *D. huttonii*, as would have been expected had he regarded the two as synonymous. There seems little justification for Hutton's supposition that the two birds are identical.

Although Owen gives certain measurements of the tibio-tarsus of his *D. didinus*, it would be impossible to obtain very accurate figures, as the bones were and still are covered almost entirely by dried skin and muscle. And, as a matter of later knowledge, Dr Andrews (1897), in his account of the skeleton of *Megalapteryx tenuipes* Lydekker, points out that *D. didinus* Owen is generically, but probably not specifically, identical with it: though Oliver (p. 42) regards them as synonymous. As will be seen later in this article, the characters of the skull of *M. tenuipes*, i.e., *M. didinus* Owen, differentiates it from the present skull, which agrees with Hutton's "*didinus.*"

Nomenclature of the Genus.

The limits placed by different authors on the various genera are very vague, and the number of genera has been multiplied from time to time and later again reduced, so that synonyms are plentiful. It will be wisest, I think, to follow Oliver's arrangement.*

Owen places his "didinus" in the genus Dinornis, but Hutton included his species in his genus *Mesopteryx* in 1891, as also did Parker in his memoir on the skulls of the moas (1895), but Hutton in 1894 recognised that Haast's genus *Meionornis* of 1873 should take precedence. Oliver does not recognise either of these generic names, and allots the species "huttoni" to the older genus Emeus.

Oliver includes Hutton's *Euryapteryx compacta* as a synonym of his *Meionornis didinus* (Hutton) solely on the similarity in leg measurements.

THE DESCRIPTION OF THE SKELETON.

Dimensions of the Leg Bones.

As Oliver uses centimetres in all his measurements, I will follow him here.

	Length.	Breadth. Proximal	Breadth. Middle	Breadth. Distal	Girth at Middle.
Femur	22.4	8.1	3.2	8.9	11.5
Tibio-tarsus	35.8	9.7	3.5	5.5	9.0
Tarso-metatarsus .	16.3	6.2	3.0	7.4	9.0

PERCENTAGE OF BREADTH TO LENGTH.

	Length.	Breadth. Proximal	Breadth. Middle	Breadth. Distal.
Femur . ..	100	36	14.2	39.7
Tibio-tarsus ..	100	27	9.7	15.3
Tarso-metatarsus ..	100	38	18	45

The breadth at the proximal end of femur is taken along the axis of the head, as Owen measured it. The dimensions of all the bones were taken between two vertical uprights. Hutton does not mention how he took his measurements; in earlier days, at any rate, he seems to have used a tape, and gives his figures in inches.

The girth is liable to vary with the personal equation, i.e., with the precise point at which it is measured.

As it is on the proportional dimensions of the legbones that several of the genera and species have been founded, and as these bones occur more abundantly than other parts of the skeleton and are readily expressed in numerals, Oliver makes use of these proportions as diagnostic characters and gives a useful " key " to the genera, using the percentage of breadth to length of each of the three bones.

From these figures it will be seen that if we take first the percentages of the breadth at the proximal, middle, and distal extremities in the case of the femur, these numbers—36, 14.2, 39.7—approach most nearly to the figures given by Oliver for the genus Dinornis (p. 35), which are 35, 16, 40.

But the tibio-tarsus of our skeleton has the percentage proportions 27, 9.7, 15.3, which represents a bone of greater stoutness than Dinornis, but agrees well with those of Anomalopteryx, in which the corresponding figures are 27, 9, 14. On the other hand, the tarso-metatarsus in its percentages of 38, 18, 45 indicates either the genus Anomalopteryx (35, 20, 45) or the genus Emeus with 38, 21, 47.

It is here that the value of the skull proves itself, for in the former genus the temporal fossae are usually large and the temporal and lambdoidal ridges are confluent, whereas in Emeus these are

widely separated and the temporal fossae are small (see Parker). Thus, if we had only the legbones before us the bird would have been placed in the former genus, but as we have the skull to take into account, it falls into the genus Emeus as used by Oliver, that is, into Hutton's genus Mesopteryx or Haast's Meionornis.

Leg bones of this species, *Emeus (Meionornis) huttoni* have been recorded from the following localities in the South Island. It does not appear to have lived in the North Island.

Under the Specific name.	Author.	Locality.	Date.	Reference.
A. didiformis	Haast	Glenmark, Canterbury	1868	Trans., Vol. 1, p. 23
B. didiformis (?) .	Hutton	Hamilton Swamp, Otago	1874	Trans., Vol. 7, p. 278
C. Mesopteryx didina	Hutton	Enfield, South Canterbury	1892	Trans., Vol. 25, p. 15
D. Euryapteryx compacta	Hutton	Enfield	1892	Trans., Vol. 25, p. 11
E. Meionornis didinus .	Hutton	Kapua, Canterbury	1895	Trans., Vol. 28, p. 636

As to D., Oliver regards this species as synonymous; but there is some doubt.

In 1896, p. 559, Hutton brings together the average dimensions of numerous legbones of " M. didina " obtained at Glenmark, Kapua, and Enfield; and a comparison with the dimensions of the present skeleton indicates that it is a small variety of the species.

It occurred to me that this might be a sexual difference, as the presence of egg shells with the skeleton indicates that it is a female. But Hutton (1894, p. 636) writes: " We have only a single point of concentration in each bone showing that there was no difference in size between the sexes." So perhaps it is a climatic variety, as Southland has a cooler mean annual temperature than Canterbury.

I am loth to form a new species, as we are in ignorance of the range of variation in size for any species of moa. For completion, I add the dimensions of the bones of the old skeleton in this Museum that has masqueraded under the title of "*A. parvus.*"

	Length.		Breadth.	
		Proximal.	Middle.	Distal.
Femur	23.2	8.6	3.5	9.3
Tibio-tarsus	37.	10.8	3.9	6.
Tarso-metatarsus .	18.3	6.3	3.5	7.8*

* The distal extremity is worn and broken.

* A good instance of the task of deciding the question is to be seen in Archey's article on the skull of "Cela geranoides," where he discusses the difficulty of arriving at a conclusion as to what genus the specific name "geranoides" should be allotted. Oliver, however, places the species, including Archey's specimen, under the title of *Emeus exilis*, a bird which Hutton attributed to Euryapteryx!

Oliver (p. 49) gives the following figures for "the type of *D. huttonii*" from the Hamilton Swamp as having length 38.6, br. 11.4, distal br. 6.3 cm. He refers to Hutton's article in Vol. vii, p. 275, but the table of measurements of "didiformis" are given on p. 278 as the mean length of 7 tibiae is 14.8 inches, prox. width 4.3, and distal width 2.2 inches, which, converted into centimetres, are 37.5; 10.9; and 5.5 respectively. Oliver seems to have made a slip in his figures.

The Foot.

The only complete digit is the middle one of each foot, which measures 126 mm. in length. There is no sign on the tarso-metatarsus of a facet for a fourth digit.

In addition to the complete middle toe of each foot, the basal phalanges of both inner and outer toes of the right foot, and of the inner toe of the left foot, as well as two odd phalanges that do not fit serially, were collected.

There is also one toe with four phalanges which differs in colour from the rest and is somewhat worn as if it has been exposed to the air. It may be the second toe of one foot, but the dimensions are smaller than one would expect; it may have belonged to another individual.

The Skull (Figs 1, 2, 3, 4).

The bird had a small head with a short, bluntly pointed beak, in which the culmen slopes up quite gradually from the tip. In general form it resembles the photograph of Emeus (species not stated) in Oliver's book, p. 47, rather than that of Emeus on pl. lvi of Parker's memoir, for they used the words with somewhat different meanings.

Parker has given so lucid and detailed an account of the moa skull that it is only necessary to refer to a few points which are characteristic of the species.

The roof of the cranium is somewhat elevated between the post-orbital processes producing a distinct hillock, which is separated from the convex area between the orbits by a slight depression. Such a hillock, though less pronounced, is seen in Archey's figure of *Cela geranoides* and is shown in Parker's silhouettes of "Mesopteryx casuarina" as well as in the species α, β, γ, and especially in the last (which is *E. huttoni*).

The roof of the orbit makes a continuous circular curve, with well-developed, stout, broad post-orbital process, the anterior margin of which has a slightly forward inclination; its lower end is broad and rounded. The circular curve of the orbital roof is in part due to this forward inclination of the postorbital process. The supra orbital fenestra is oval.

The tympanic cavity is large (much larger than in *M. tenuipes*, to which this skull bears some resemblance), its upper border makes with its posterior boundary nearly a right angle; and its anterior limit is formed by the pointed zygomatic process.

The temporal fossa is small, does not encroach on to the roof of the cranium; its upper boundary, the temporal ridge, is separated from its fellow by almost the entire breadth of the cranial roof; posteriorly there is a smooth area between the temporal ridge and the anterior lambdoidal ridge which is distinct from the posterior lambdoidal ridge.

The paroccipital processes reach down to the level of the lower surface of the basitemporal; in the figure they appear to extend much further, but this is due to the fact that the photograph is taken rather from above; it is oblique, and not actually a back view.

The rostrum of the basisphenoid is rounded below, the margin of the eustachian groove, which traverses the basi-temporal, ceases before it reaches the mid-line, and here the basitemporal bone is somewhat raised and roughened.

The skull is quite evidently that of a "Mesopteryx," of which genus Jeffery Parker describes and figures in detail the skull of *M. casuarina* (pl. lx, fig. 12) and gives silhouettes from different aspects of three species which he terms α, β, and γ; (pl. lxi, lxii). The last species is drawn, he says, from the skull "mounted on the skeleton of *M. didina* from Hamilton Swamp (Otago University Museum)," p. 378. I was puzzled by the reference, as there is no skeleton so named in our collection; the only possible one was labelled "Anomalornis parvus." A comparison of this with Owen's account of the species showed at once that this skeleton had been labelled wrongly.

A comparison of the dimensions of the leg bones with those of *D. parvus* and later with Hutton's "didina" (i.e., *D. huttonii* Owen), as well as the comparison of the silhouettes of the skull in Parker, proved that the skeleton had thus been wrongly labelled all these years. It is evidently one of the birds referred to by Hutton as "didiformis" from the Hamilton Swamp, obtained in 1874, while he was curator of this Museum. I have been unable to decide whether it is an "individual" skeleton, but I think not. It is fairly complete, though several of the vertebrae are lacking, and the sternum and pelvis are imperfect.

The skull of this species, which as I have noted is Parker's "species γ," agrees quite closely with the skull from Wakapatu except in its slightly greater length.

Parker speaks of the upper margin of the orbit as being "right-angled in species γ" (i.e., the former "didina"), and so represents it in exaggerated state in the silhouette. An examination of the specimen, however, shows that the supraorbital crest has been cracked in its upper region, and the bone has shrunk apart here; it has been varnished, and is easily mistaken for a natural angular outline; it is really artificial.

None of the skulls of which Parker, on p. 408, tabulates the dimensions has such a short length as 100 mm., but the other measurements are in very close agreement, many being exactly the same as for those given for "didina."

It is the shorter beak that accounts for the relative shortness of the skull. The nasal processes of the premaxillae had been broken across, but no part of it appears to be missing; and it has been carefully repaired, the edges fit, yet it may be a few millimetres short of its actual length.

The skull of *E. casuarinus* differs from that of *E. huttoni*, apart from its greater size, in the following points:—The greater breadth of the postorbital process; the temporal ridge is more marked, being rougher; the supraorbital fenestra is circular; the occipital crest is better developed. The posterior border of the basitemporal is nearly straight, with a vertical drop to the basioccipital, instead of a slope. The paroccipital processes are broader and less pointed. The basisphenoidal rostrum is keeled, not rounded; the basipterygoid processes are relatively longer; the posterior margin of the eustachian groove extends across the basitemporal, then curves backwards and meets its fellow (whereas in *E. huttoni* the groove ceases before it reaches the median line). At the mesial end of the groove the basitemporal is smooth and flat or only slightly convex (whereas in *E. huttoni* this area is raised and roughened).

Dimensions of the Skull in Millimetres.

The series of measurements are in accordance with those tabulated by Parker. Those in brackets are additional to his.

Total length	100
Length of basis cranii	30
Length of roof of cranium	67
Width at paroccipital processes	48
Width at squamosal processes	59
Width at temporal fossae	45
Width at postorbital processes	62
Width at preorbital processes	36
Width between the temporal ridges	43
(Width at middle of supra-orbital plates	44)
Height of cranium	41
Width of tympanic cavity	17
Width of temporal fossa	14
Width of orbit	25
Distance between the optical foramina	9
Length of premaxilla	44
Length of body of premaxilla	21
Width of body of premaxilla	20
Length of mandibular ramus	98
Length of mandibular symphysis	13
Width of mandibular symphysis	17
Greatest height of mandible	17
Least height of mandible	8
(Least distance between the supra-temporal ridge and anterior lambdoidal ridge	9)
(Occipital foramen; horizontal diameter	13)
(Occipital foramen; vertical diameter	11)

To complete the list, mention may be made of a much damaged skull which Hutton describes (1896, p. 561) under the title of *Megalapteryx tenuipes*, which was associated with bones that Hutton attributed to his species. Parker (p. 378, footnote), however, identified it as agreeing very closely with that of Mesopteryx γ (i.e., "didina" of his memoir). It was found in a cave on the Lower Buller River on the West Coast of the South Island.

The few measurements are:—

Length of basis cranii	28 mm.
Width at temporal fossae	38
Height of cranium	33
Distance between the optic foramina	9
Vertical diameter of occipital foramen	11
Horizontal diameter of occipital foramen	10

Hutton (1891) also gives a few measurements in inches of the skull of "M. didinus" (p. 130). Taking the higher of the two figures he gives for each of the measurements and converting them into millimetres, we have:—

Breadth at temporal fossae	48.45 mm.
Breadth at post-frontal processes	71.4
Length of lower jaw	108.37
Total length of "head"	127.5

The skull agrees in several respects with that of *Cela geranoides* described and figured by Archey in 1927. The present skull is 16 mm. shorter, and its height is 2 mm. greater; the length of basis cranii, of roof of cranium, width at paroccipital processes, at temporal fossae and squamosal are almost or quite identical. But the width between the temporal ridges is much less in our skull, less by 11 mm.; the width of the temporal fossa is likewise 11 mm. less in *E. huttoni* than in *Cela geranoides*. It has also a shorter premaxilla. But the birds were about the same size.

The Sternum (Fig. 5).

The shape of the sternum is very similar to that of *E. casuarinus*. The anterior margin is nearly straight, and is, as usual, abruptly bent upwards so that its dorsal edge is here 22 mm. above the level of the under surface of the body of the bone. This margin is produced laterally to form the pre-costal or antero-lateral process on each side, the distal end of which is dilated so as to form a knob, elongated in the antero-posterior direction, which is 20 mm. across its roughened surface.

The costal border, which is 30 mm. in length, presents two facets for the two sternal ribs; they are smooth and separated by a roughened area, and the posterior facet is bounded behind by a roughened prominence. A pneumatic foramen precedes the first facet.

There is really no coracoid pit, there being but a shallow, widely open furrow at the base of the precostal process. The body of the sternum is almost square, but is slightly broader than its length, as

measured from the precostal process to the outer origin of the xiphoid or lateral process; this latter extends outwards and backwards at a slight angle, and its free end is external to a line taken from the tip of the precostal process parallel to the lateral margin of the body. The two xiphoid processes are thus not very divergent. One of them is broken near its tip, but the other is entire and has a truncated end.

The median process, which is really the narrowed continuation of the body, extends further backwards than the xiphoids, and is notched at its extremity, though the sides of the notch are not symmetrical.

Dimensions of the Sternum in Millimetres.

Breadth across the tips of precostal processes (b)	131
Breadth of body at anterior end of costal border (a) . ..	96
Length from anterior margin to tip of median process (d) ..	176
Length from anterior margin to tip of xiphoid process (e) ..	160
Length from anterior margin to bottom of notch betwen xiphoid and median process (c)	73
Breadth of median process at level of bottom of the notches (f)	65
Breadth of median process near its tip	23
Distance between outer ends of xiphoids (g) .. .	165
Breadth of xiphoid near tip	9
Length of costal border	30
Length of pre-costal process from pneumatic foramen	35
Breadth of its distal end	20

The two sternal ribs vary in their length on each side:—

Right side: First rib, 59; second. 80.
Left side: First rib, 58; second, 81.

Figures of the sternum of moas are few in number. Owen (Ext. Birds N.Z.) shows that of *E. elephantopus* (pl. lxxii), of *E. casuarinus* (pl. lxxiii, lxxiv), of *Dinornis robustus* (pl. xcvi), and of *D. maximus* (xcviii), while Oliver gives illustrations for Anomalopteryx and of Dinornis.

The Pelvis (Figs. 6, 7, 8).

The pelvis is entire except that a small portion of the ventral margin of the pre-acetabular plate of the ilium is broken away; and owing to the brittleness of the bones the ischium and the pubis were broken across on one side during transport, but were repaired without any part being lost.

It presents no peculiarities. The dorsal margin of the ilium is nearly a straight line, formed by a narrow ridge in the pre-acetabular region where the bones of the right and left sides meet the greatly compressed neural spines of the anterior sacral vertebrae. This ridge extends forwards till it meets the neural spine of the

28th vertebra; the first of the synsacral series. In front of this point the two ilia diverge slightly, and the anterior margin of each bone curves rather abruptly downwards to meet the ventral horizontal margin at an angle which is nearly 90°. (Fig. 6.)

The extreme tip of the ilium is 42 mm. in front of its point of attachment to the 28th vertebra and lies at the level of the 27th.

The outer face of this pre-acetabular region slopes down at a steep angle to its ventral margin, and its surface is somewhat concave. Two short ribs, broken short, belonging to the 29th and 30th vertebrae, project beyond its margin.

The " iliac ridge " extends back to about the level of a vertical line through the anterior border of the acetabulum; behind this point the ridge divides into two, which diverge above the acetabulum, and each is continued along the post-acetabular region, separating the ilium into two areas, an upper horizontal plate (the " pelvic roof " of Owen) and a vertical lamina. (Fig. 7.)

The horizontal plates diverge in an elegant curve and enclose between them the thin plate of bone formed by the expanded ends of the neural spines of the posterior sacral vertebrae (the " sacrum " of Owen) which is 51 mm. across its widest part, and is anchylosed to the horizontal plates on each side. As will be seen from the figure, this plate does not reach to the hinder end of the ilia, but tapers to a point. The " pelvic roof " or horizontal plate of ilium, which is 47 mm. wide, is separated from this median plate by a row of holes. The " pelvic roof " plus the " sacrum " is the pelvic " escutcheon." The outer edge of this portion of the ilium descends abruptly to form a vertical lamina some 40 mm. in height, which is continued to the hinder end of the pelvis.

The ventral border of this plate is gently curved; at first, immediately behind the acetabulum, it is concave, so that some of the sacral vertebrae are visible from the side; further back its margin is convex and completely hides the vertebrae.

The ischium, narrow at its origin, widens posteriorly and terminates at a vertical line through the hindmost end of the ilium. The pubis, though more slender than the ischium, is of greater length; at its origin, below the acetabulum, it is roughened as a " pectineal tuberosity," its hinder end curves upwards rather abruptly and terminates somewhat beyond the end of the other two bones of the pelvis.

It may be worth while to comment of the great difference between the pelvis of the Dinornithidae and the living Ratite birds, in which the " pelvic roof " is either quite narrow, as in *Struthio*, or is totally absent as in the rest; and the ilia, instead of diverging behind the acetabulum and leaving a wide area occupied by the " sacrum " or plate of bone formed by the expanded neural spines, are here parallel to one another, and the post-acetabular space is either quite narrow, or is absent in *Apteryx* and *Rhea;* here the two ilia meet above the sacral vertebrae.

Does this difference indicate a different phylogeny? That it has nothing to do with the walking habit is clear from these differences and from the fact that these two features—a "pelvic roof" and a wide "sacrum"—are present in various flying birds, such as the storks, the parrots, and ducks; birds of widely different habits and relations.

Dimensions of Pelvis.

Pelvis as a whole:—

Total length	350
Greatest breadth across the antitrochanters	165
Breadth across the "escutcheon"	140
Breadth measured ventrally at level of pectineal tubercles	120
Diameter of acetabulum	30

Ilium:—

Pre-acetabular length from anterior margin of acetabulum to anterior end of ilium	148
Length from posterior margin of antitrochanter to anterior end of ilium	212
Post acetabular length from posterior margin of acetabulum to posterior end of ilium	170
Greatest height of pre-acetabular region in front of origin of pubis	85
Greatest height of post-acetabular region	40
Breadth of dorsal horizontal plate	47
Distance between the ventral edges at anterior end	80
Distance between ventral edges at posterior end	80

Ischium:—

Length from posterior margin of acetabulum	178
Length of free portion, measured from bottom of ilio-ischiac notch	170
Height (width) of free extremity	51
Distance between the distal ends (ventral edges of ischia)	180

Pubis:—

Length from anterior margin of pectineal tubercle	235
Length of free portion, measured from bottom of ischio-pubic notch	190
Height (width) of upcurved extremity	41
Distance between the distal ends of the two pubes (ventral edges)	200

The Vertebral Column.

Hutton (1894) states that it is a characteristic feature of the Dinornithidae to possess 21 cervical vertebrae; Andrews (1897) also gives this number for *Megalapteryx tenuipes*. In the present skeleton only 20 were present, but on articulating the series I found that the 3rd and the 4th do not fit accurately. The facet on the postzygapophysis of the 3rd is elongated, and does not correspond to the prezygapophysis of the next one; the centrum is much too narrow, being 7 mm. across the posterior end, whereas the anterior end of the centrum of the next vertebra measures 10 mm. Hence I must

assume that a vertebra was overlooked in spite of the care taken by Mr Teviotdale in his desire to collect all the bones: even the Atlas and the Axis were gathered up—small bones frequently overlooked by collectors

The 21 cervical vertebrae are followed by 3 cervico-thoracics (22, 23, 24), with free ribs, three free thoracics (25, 26, 27) and three fixed thoracics fused with the sacrals (28, 29, 30), which have ribs either moveable or anchylosed with their centra.

The synsacrum consists of 18 vertebrae, commencing with the 28th with its floating ribs and ending with the 45th. The 46th is moveably articulated with the preceding, and its transverse processes are not anchylosed to the ilia. I find the same numbers in the old skeleton in the Museum Hutton (1894) states that the sacrum of this species consists of only 17 vertebrae.

Owen (1875) has given excellent figures of the vertebrae of *D maximus*, and Hutton's account is sufficiently detailed, so that it is only necessary here to record any differences in specific characters He gives details for its ally *E casuarinus* In his general account, Hutton states of the Atlas that it is "broadly oval, the larger diameter being dorsi-ventral," whereas in this species the horizontal diameter of the neural canal is 10 mm, as against 6 mm. for the vertical diameter

The *Axis*, the anterior articulating surface, is transversely oval, its height being about half its breadth. In *E. casuarinus* the "height is nearly as great as the breadth"

The odontoid process is small, projecting only 2 mm. from the centrum.

In the 3rd vertebra the neural spine is bifid (noted as being single in *E casuarinus*). It rises erectly from the middle of the neural plate, which is almost square, its posterior border being nearly straight.

The 4th vertebra is lacking

In the 5th and 6th the spine is also bifid, and from the base of each a low ridge passes backwards to be continuous with a low roughened "hyperapophysis" on the outer edge of the post-zygapophysis. To this ridge Hutton gives the name "neural ridge," which Owen calls the "hyperapophysial ridge." Hutton has called attention to this "remarkable blending of the neural spine, hyperapophysis, and postzygapophysis" as a characteristic feature of the moas.

In the following vertebrae the same condition holds, so that in the 8th a deep longitudinal trough traverses the neural plate from the bases of the conjoined neural spines to the posterior margin of the neural plate. Here these "neural ridges" are nearly parallel.

Further backwards the distinctness of the spine becomes less, as they diverge from one another and lose in height till they become reduced to mere knobs at the anterior ends of the "neural ridges." In the 18th, however, the spines again become independent, rising

a little above the ridges, and in the 19th the double neural spine becomes tall, fused basally; in the 20th the two are united along their whole length so as to produce a single spine, which in subsequent vertebrae increases in height.

The centrum bears a hypapophysis in the 3rd to 18th vertebrae. In the 3rd it is stout and single, as in the Axis, but in the 5th it is absent. In the 6th, 7th, 8th, and 9th vertebrae, in place of the hypapophysis, there is a pair of widely separated low tubercles close to the base of the ribs; these are the "parial hypapophyses" of Owen or "catapophyses" of Mivart. These knobs become successively more prominent in the later vertebrae up to the 16th. In the next they move backwards and come to lie behind the rib, and they increase in length so that in the 18th they form definite spines and, moving inwards, become united at the base so as to produce a forked process, the two forks of which in 19-21 become completely fused together to form once more a median hypapophysis; short, almost cylindrical and vertical.

Posteriorly to the 22nd the hypapophysis decreases in height, and its base moves towards the anterior end of the centrum; and once more it is represented in 27th by a mere nodule, which disappears in the 28th.

Another feature is the "inter-zygapophysial canal" of Owen (which Hutton does not describe). In the 3rd there is a small foramen near the middle of the outer margin of the neural plate which is bounded externally by a bony bar, called by Owen the "interzygapophysial bar." In the 5th the foramen enlarges and is situated further back, and the "bar" is seen to extend from the postzygapophysis to the transverse process.

In the 6th, the "bar" is broader and longer as the transverse process moves outwards from the neural plate so that a broad bridge is formed above the canal, which runs fore and aft between the neural plate and the transverse process. Its anterior opening is between the prezygapophysis and the neural spine; its posterior opening is between the sides of the neural arch and the transverse process. This canal, larger in the earlier vertebrae, decreases in diameter till the 13th, when it is little more than an oval slit. In the next it is a small pore, and in the 16th is reduced to a pit the size of a pin's point.

The structure of the cervico-thoracics and of the thoracic vertebrae present no differences from Hutton's account.

The Ribs.

There are nine pairs of ribs, seven of which are moveable, followed by two pairs of immoveable ribs borne by the two first vertebrae of the synsacrum.

The first rib, borne by the 22nd vertebra, is lacking in our skeleton, and, judging from the capitular facet, it is small; the second rib (23rd vert.) is short, and ends freely. The third is longer, but is also a floating rib. These three constitute the "cervico-thoracic ribs."

The true thoracic ribs commence with the 25th vertebra—this and the next are attached to the sternum by sternal ribs; the next two (27th and 28th vertebrae) are floating. The ribs of the 29th and 30th vertebrae project beyond the edge of the ilia—the former is broken off about one inch from the pelvic bone; the latter about half an inch beyond it.

The length of the ribs, measured in a straight line from the upper surface of the tuberculum to its distal extremity, is as folows: -

	Length of Ribs in Millimetres.	
	Right side.	Left side.
1st	Lacking	Lacking
2nd	65	60
3rd	130	119
4th	160	160
5th	177	163
6th	168	162
7th	113*	127

* Is broken.

I find in our skeleton of *Anomalopteryx didiformis* that there are only two pairs of cervico-thoracic ribs (21, 22 vert.); two pairs of complete ribs; three pairs of floating (25, 26, 27); and three belonging to the first three vertebrae of the synsacrum.

Uncinate processes are borne by the 3rd, 4th, and 5th ribs of the 24, 25, and 26 vertebrae; that of the 3rd rib is anchylosed to the rib on both sides, as is that of the 4th of the right side; the rest are not fused. The form of the Uncinate (Fig. 9) may be described as a right-angled triangle, with a rounded apex, a somewhat convexly curved hypotenuse, and a slightly concave vertical side. That of the 2nd complete rib measures 42 mm. in length, with a base of 12 mm. Its shape is much simpler than that of *A. didiformis*, in which the base is much longer; the upper border starts as a nearly straight line, but then curves upwards to produce a recurved hooked tip. The base is 30 mm., its length is 38 mm., and depth 55 mm., so that, although the skeleton is approximately the same size as that of *E. huttoni*, the uncinate is much larger. (Fig. 9.)

The Synsacrum (Fig. 8).

The synsacral series consists of 18 vertebrae, namely, the 28th to the 45th inclusive. Hutton gives 17 as the usual condition. The first three of them bear ribs, the first being moveable, the other two fixed to the centrum. That of the 29th exhibits a suture at the capitulum, and its tuberculum articulates with the transverse process just within the edge of the ilium. (In our old skeleton of this species the head of the second rib is moveably articulated with its centrum.) These three vertebrae would be called the " thoraco-sacrals."

The 31, 32, 33 vertebrae have short, broad, transverse process (? ribs) which are vertically extended as they meet the ilia to which they are of course anchylosed. The process of the 34th is very much

FIG 1 —Photograph of the skull of *Emeus huttoni* Natural size The difference in colour of the bones of the lower jaw and quadrate is due to preservation they have not been interfered with in any way As certain outlines and ridges do not show up distinctly in the photograph they have been inked in in this and following figures

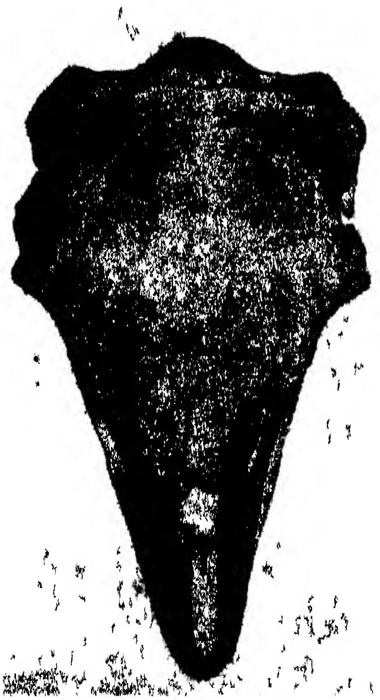

FIG 2 —Dorsal view of the skull (Four fifths natural size)

FIG 3 —Ventral view of the skull (Four fifths natural size)

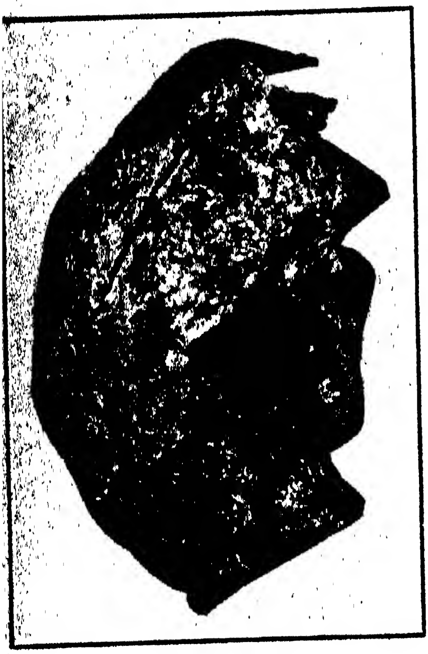

FIG. 4.—Posterior view of the skull (natural size). It is unfortunately not quite truly posed, so that the paroccipital processes appear to reach further down than in reality.

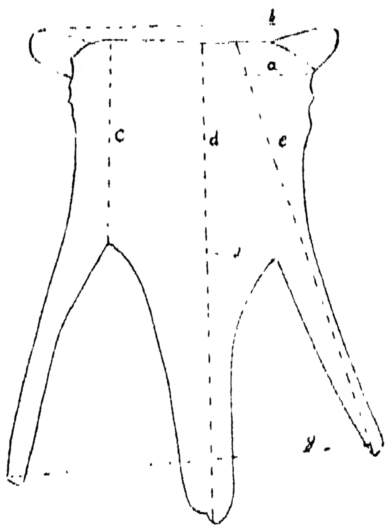

FIG. 5.—The sternum, in outline, traced on a photograph (about one-third the natural size). The dotted lines show the various measurements mentioned in the text.

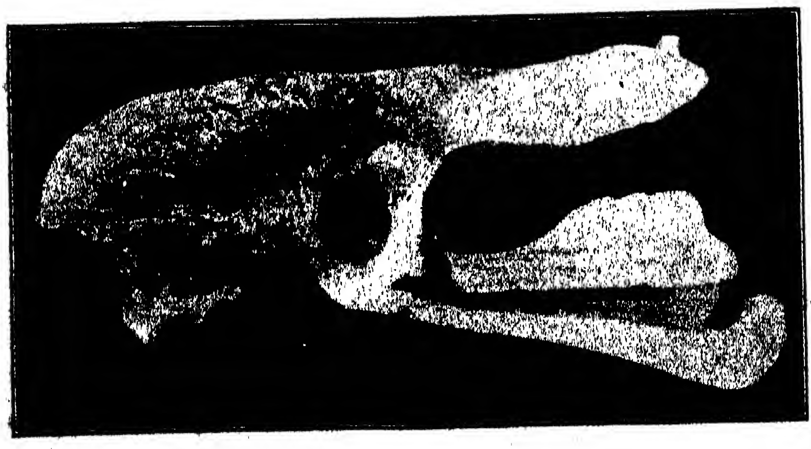

FIG. 6.—The pelvis, side view (about one-quarter natural size).

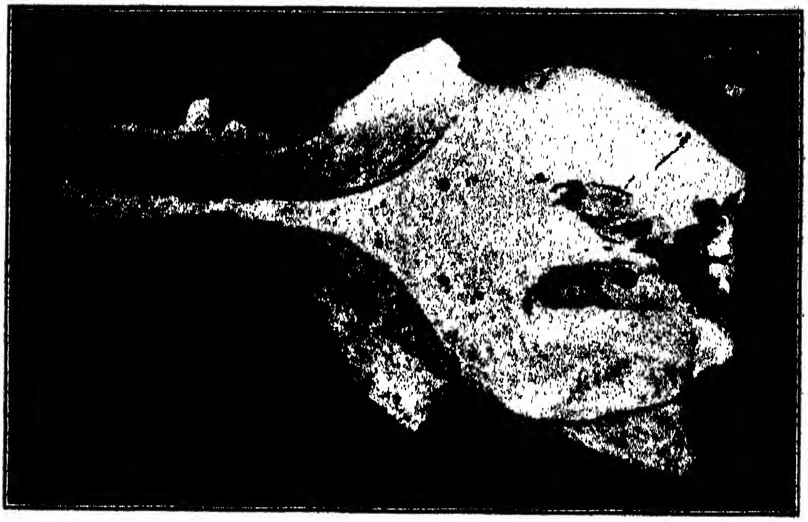

Fig. 7.—Dorsal view of pelvis. (× ½.)

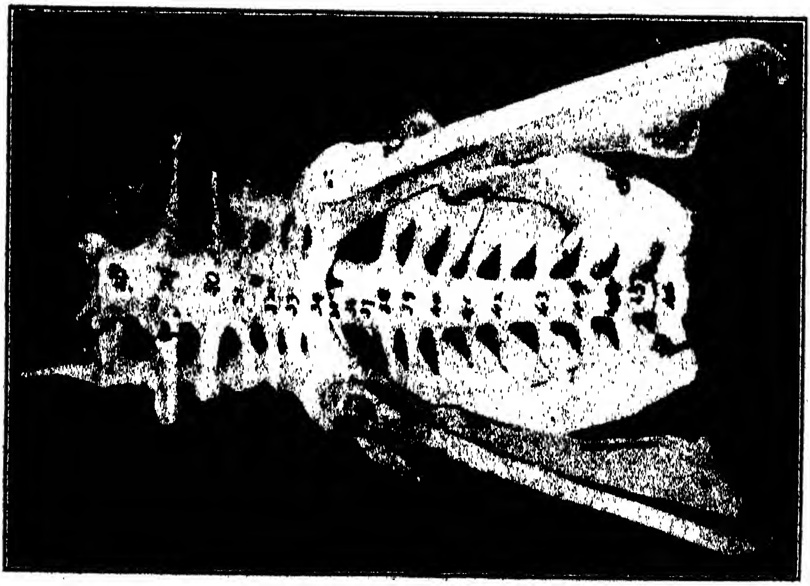

Fig. 8.—Ventral view of pelvis. The constituent vertebrae of the synsacrum are numbered. (× ½.)

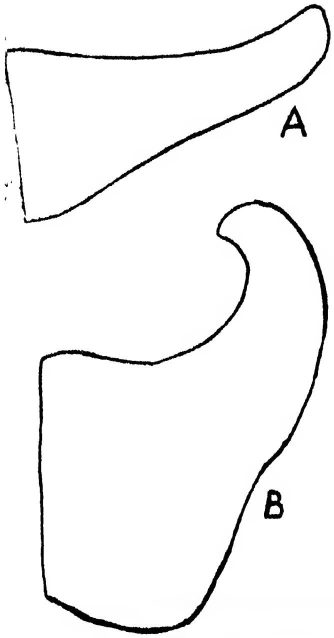

Fig. 9.—An uncinate process.
A of *E. huttoni*; B of A. *didiformis*.

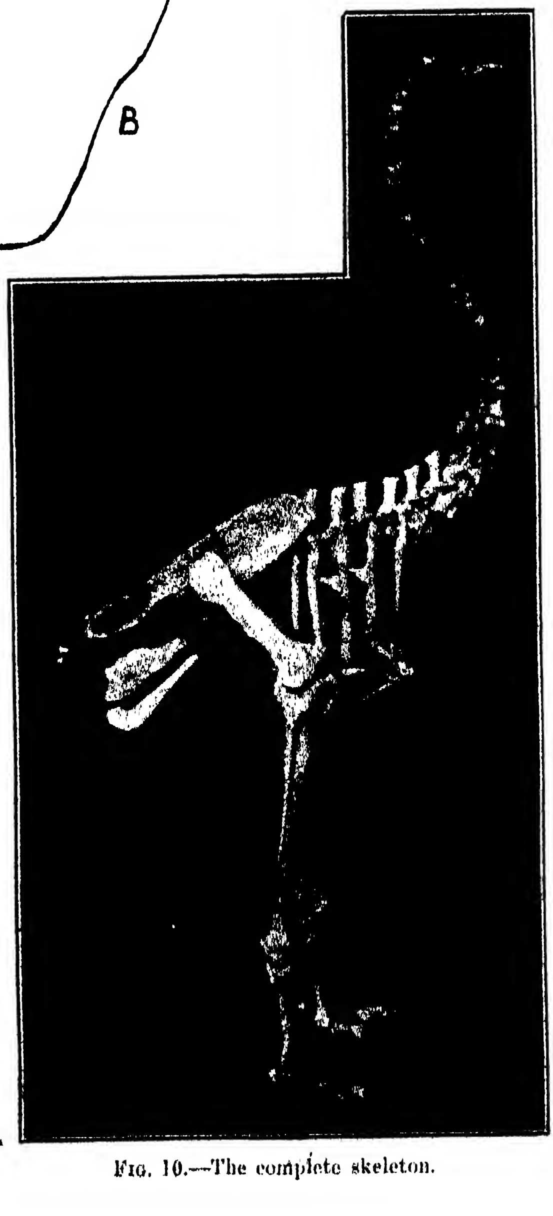

Fig. 10.—The complete skeleton.

stouter than the preceding or the following and are more ventrally placed, directed backward, dilating distally to abut on the lower wall of the acetabulum. These four are the "lumbo-sacrals."

The transverse processes of the 35th is very slender, is directed towards the same place, but is almost concealed by the previous process on the right side and entirely so on the left.

The transverse processes of 36, 37 are absent, leaving a gap in the series, the "pelvic fossa." These two correspond to the "true sacrals."

The processes of the remaining vertebrae, 38th to 45th, are stout; are expanded as they pass outwards into almost horizontal plates so as to come into contact with one another, or even to fuse, where they abut on the postacetabular region of the ilia; these eight processes are at a more dorsal level than the preceding.

The 46th, though similar in form to those immediately preceding, is, however, not fused with them, and its transverse processes are not anchylosed to the ilia.

The neural spines of most of these "caudosacrals" are expanded so as to form a horizontal plate fused for most of its extent to the hinder part of the ilia, forming the "sacrum" already described.

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Explanation of Figures.

1. Photograph of the skull of *Emeus huttoni*. Somewhat larger than its true size. The difference in colour of the bones of the lower jaw and quadrate is due to preservation; they have not been interfered with in any way. As certain outlines and ridges do not show up distinctly in the photograph, they have been inked in.
2. Dorsal view of the skull.
3. Ventral view of the skull.
4. Posterior view of the skull. It is unfortunately not quite truly posed, so that the paroccipital processes appear to reach further down than in reality.
5. The sternum, in outline, traced on a photograph (about two-thirds the natural size). The dotted lines show the various measurements mentioned in the text.
6. The pelvis, side view (about three-eighths natural size).
7. Dorsal view of pelvis.
8. Ventral view of pelvis. The constituent vertebrae of the synsacrum are numbered.
9. An uncinate process. A. of *E. huttoni*; B of *A. didiformis*.
10. The complete skeleton.

On some Phyllocarids from the Ordovician of Preserv Inlet and Cape Providence, New Zealand.

By FREDERICK CHAPMAN, A.L.S., F.G.S., F.R.S.N.Z.
(Commonwealth Palaeontologist).

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INTRODUCTION.

DURING the investigation of the rich graptolitic Ordovician fauna of Preservation Inlet, New Zealand, by Prof. W. N. Benson and Mr R. A. Keble, numerous examples of fossils referable to the Phyllocarida came to light. These were kindly placed in my hands by Professor Benson, for determination and description, and the following are the results of a study of the forms present in the collection.

All types have been placed in the collections of the Geology Department, Otago University.

LIST OF SPECIMEN NUMBERS, GROUPED IN LOCALITIES, BY PROF. BENSON.

(These will appear in Benson and Keble's map of Preservation Inlet.)

Nos. 2, 3, 4, 8, 9, 10, 12, and 15 are all near Cape Providence. Nos. 17 and S.P.2. = N. end of Gulches Head. No. 19 from a big boulder, and 32 North side of Coal Island.

Specimen Nos.	Locality.	Horizon.
108, 112, 137, 147	3	L 3
509, 517	2	L 3
523 to 530	17	Unknown. Possibly L 3, but quite uncertain. Traces of Graptolites indeterminate.
531 to 541	S.P.2. Southport, West Shore, N.Z.	Do. Do.
543, 551, 677	32	C 5
790	19	L 2 (probably)
797, 800, 803	12	C 4
813, 825, 830	8	B 1 (low)
972, 1015	4	L 3 (high)
1131, 1138	10	C 5
1140 to 1144	12	C 4
1169, 1193	9	B 1
1268, 1285, 1288, 1320, 1322, 1327, 1330, 1332, 1333, 1344	15	L 2 (low), associated with the big *Dictyonema macgillivrayi*

Other specimens, not localised:—

Nos. 1352, 1395, and 1427 (pebbles from Cape Providence Beach).

Also No. 1231.* "From the Cobb beds, N.W. Nelson, highest Darriwil (D 1), if not basal Upper Ordovician, to show extension of the pod-shrimps to that horizon." (W. N. B.)

* This really refers to Locality 1231 in the N.Z. Geological Survey Register, i.e., at the head of the Cobb River, a tributary of the Takaka River. (See Keble and Benson, *Trans. N.Z. Inst.*, Vol. 59, p. 841.)

ɹditional specimens, received later (1.5.33). Park. Coll. Cape dence, New Zealand. Nos. 18, 21, 42, 49, 73, 81, 85, and two s without reference-numbers. Horizon C 5 (high).

Detailed Determinations (Serial Nos.).

No. 108*a* A small form of *Rhinopterocaris,* referred to *R. bulmani* sp. nov. (See Descriptions.)

No. 108*b*. *Caryocaris marrii* Hicks. (See Descriptions.)

No. 112. *Caryocaris wrightii* Salter. A complete carapace, with convexly rolled ventral border. (See Descriptions.)

No. 137. *Hymenocaris bensoni* sp. nov. (See Descriptions.)

No. 147. *Caryocaris* cf. *marrii* Hicks. Several carapaces, more or less imperfect.

No. 509. No crustacea. *Protospongia* spicules (large cruciform type).

No. 517. *Rhinopterocaris.* A large form, probably referable to *R. bulmani* sp. nov. (See Descriptions.)

No. 523. Numerous Phyllocarid remains, including abdominal segments and tail-spines. ? *Rhinopterocaris* and *Caryocaris* cf. *minima* sp. nov.

No. 524. Phyllocarid remains, including a carapace of *Caryocaris minima* sp. nov. (See descriptions.)

No. 525. *Rhinopterocaris* and *Caryocaris*, spp. indet.

No. 526. *Rhinopterocaris bulmani* sp. nov. (See Descriptions.) Also numerous carapaces of *Caryocaris minima,* sp. nov.; *C. wrightii*, with trifid caudal appendages, and *C. marrii.* (See Descriptions.) On same slab occur long, curved, and cruciform sponge spicules.

No. 527. Counterpart of preceding. *Caryocaris minima* (trifid appendages), also *C. marrii,* and sponge spicules.

No. 528. *Rhinopterocaris maccoyi* (Eth. fil.) and other phyllocarid remains.

No. 529. Phyllocarid remains, indet.

No. 530. *Caryocaris marrii* Hicks.

No. 531. No crustacean remains.

No. 532. cf. *Rhinopterocaris.*

No. 533. No crustacean remains.

No. 534. (?)

No. 535. Crustacean remains indet. and graptolite.

No. 536. (?)

No. 537. (?) Phyllocarid, indet.

No. 538. (?)

No. 539. Numerous obscure crustacean remains, including *Caryocaris.*

No. 540. cf. *Rhinopterocaris.*

No. 541. Phyllocarid, indet.

No. 543. *Rhinopterocaris maccoyi* (Eth. fil.). (See Descriptions.) Also other phyllocarid remains together with *Phyllograptus* and other graptolites.

No. 551. No crustacea. ? *Phyllograptus* and *Didymograptus*.

No. 677. cf. *Hymenocaris*.

No. 790. *Rhinopterocaris maccoyi* (Eth. fil.) var. *tumida*, var. nov. (See Descriptions.)

No. 797. *Rhinopterocaris maccoyi* and *Caryocaris* cf. *wrightii*.

No. 800. *Caryocaris marrii*, 2 examples. *Climacograptus* on reverse side.

No. 803. *Caryocaris marrii*, with conjoined valves. (See Descriptions.) Also *Rhinopterocaris* sp. (fragment).

No. 813. *Rhinopterocaris maccoyi*.

No. 825. *Hymenocaris lepadoides*, sp. nov. (See Descriptions.)

No. 830. *Rhinopterocaris maccoyi;* carapace well-preserved.

No. 972. *Caryocaris wrightii*.

No. 1015. No crustacea determinable.

No. 1131. *Caryocaris* cf. *marrii;* also impression of ? brachiopod, cf. *Orbiculoidea*.

No. 1138. Phyllocarid remains, indet.

No. 1140. *Rhinopterocaris maccoyi;* with deep ventral flange; also *Caryocaris marrii*.

No. 1141. Counterpart of 1140; same fossils as above. On reverse side similar species, also graptolites—*Phyllograptus* and *Isograptus*.

No. 1142. *Lingulocaris* cf. *acuta* Bulman (pars.). (See Descriptions.) Also graptolites, *Phyllograptus* sp.

No. 1143. ? *Hymenocaris* sp. (Badly preserved.)

No. 1144. *Rhinopterocaris maccoyi* and *Caryocaris* sp. Specimens badly preserved.

No..1169. *Rhinopterocaris maccoyi;* several carapaces, one extremely good. Also *Caryocaris* sp.

No. 1193. Counterpart of 1142, with *Lingulocaris* cf. *acuta* (Bulman). (See Descriptions.) On reverse side a fine example of *Rhinopterocaris maccoyi* (broad form) and *Caryocaris* sp. (Counterpart of 1169.)

No. 1231. Indet.

No. 1268. Indet.

No. 1275. *Caryocaris* sp.

No. 1288. ? *Rhinopterocaris maccoyi* (Eth. fil.), with cercopods.

No. 1320. Ditto. Counterpart of 1288. (See Descriptions.)

No. 1322. *Caryocaris* spp., including *C. wrightii*.

No. 1327. *Caryocaris* sp.

No. 1330. *Caryocaris wrightii.*

No. 1332. *Caryocaris wrightii.*

No. 1333. *Rhinopterocaris maccoyi* (small carapace).

No. 1344. *Caryocaris wrightii,* also sponge spicules.

No. 1352. *Caryocaris marrii.* Also *? Phyllograptus.*

No. 1395. ? Crustacea represented by carbonaceous patches.

No. 1427. *Rhinopterocaris* and *Caryocaris* sp.

Additional Specimens (received May, 1933)
Park. Coll. Cape Providence, N.Z.

No. 18. A slab of black shale with several very finely preserved carapaces of *Rhinopterocaris maccoyi* (Eth. fil.), one having a length of 38 mm. Associated with these are *Phyllograptus* sp. and *Isograptus caduceus* and vars.

No. 21. *Rhinopterocaris bulmani* sp. nov. Associated with other indeterminate phyllocarid remains, and *Didymograptus bifidus.*

No. 42. cf. *Rhinopterocaris.*

No. 49. cf. *Rhinopterocaris.*

No. 73. *Caryocaris* and other doubtful phyllocarid remains.

No. 81. cf. *Rhinopterocaris.*

No. 85. *Rhinopterocaris* and other undet. phyllocarids.

Unnumbered Specimens.

(a) *Rhinopterocaris maccoyi.*

(b) Several carapaces of *Caryocaris marrii* Hicks and *C. wrightii* Salter. Also *Didymograptus bifidus.*

Description of New Species and Figured Specimens.

Sub-Class *ENCRUSTACEA*
Division *PHYLLOCARIDA*
Fam. *HYMENOCARIDAE*
Genus *HYMENOCARIS* Salter.

HYMENOCARIS BENSONI, sp. nov.

Plate 9. Fig. 1.

Description.—Carapace elongately ovate; gently curved dorsally, more strongly curved ventrally; anterior margin deeply serrate. Abdominal segments attenuated and inwardly curved towards the posterior part of the carapace; distal extremity uncinate. Abdominal segments approximately six, but actual sutures obscure. The proportionate length of the carapace slightly longer than that of the abdominal region. Height of highest part of carapace equals one-third its length. Extremity of abdominal series probably in the form of blunt stylets. Surface of carapace longitudinally and obliquely wrinkled.

Dimensions.—Entire length of carapace and abdominal region, 24 mm.; length of carapace, 14.25 mm.; height of carapace, 4.3 mm.

Observations.—This form differs from known species of *Hymenocaris* in its greatly elongate carapace, but the relation of the abdominal segments to the carapace warrants its inclusion in that genus. In general appearance it compares with some elongately extended varieties of *H. vermicauda* Salter (see Jones and Woodward, 1892, pl. xiii, fig. 4). In the ragged denticulated anterior margin, the specimen shows an affinity with *Rhinopterocaris*, but otherwise it is quite distinct from that genus. *H. bensoni* is named in acknowledgment of Dr W. N. Benson's courtesy in placing these specimens in my hands for description.

Locality.—No. 139. Loc. 3. Preservation Inlet, New Zealand.

Horizon.—L 3.

HYMENOCARIS LEPADOIDES, sp nov

Plate 9. Fig. 2.

Description.—Carapace with dorsal edge incomplete, but evidently elongately triangular; anterior angle produced and acute; ventral margin convexly rounded behind and concave in front. Abdominal portion flexed, vermiform, separate segments not visible Surface marking consisting of a few undulating growth-lines parallel with antero-ventral margin. Terminal segment of abdomen with two short, acute stylets.

Dimensions.—Length of specimen, 19 mm ; length of carapace, 11.5 mm.; length of abdomen, 2.5 mm.

Observations.—The trivial name is given for its resemblance to a scutum of *Lepas*. It is quite distinct from *H. vermicauda* Salter, because of its flexuous trigonal outline.

Locality.—No. 825, Loc. 8. Preservation Inlet, New Zealand

Horizon.—B 1 (low).

Fam *CERATIOCARIDAE*

Genus *CARYOCARIS* Salter

CARYOCARIS WRIGHTII Salter.

Plate 9. Figs. 3, 4.

Caryocaris wrightii Salter, 1863, pp. 135, fig. 15, pp. 137 and 139. Jones and Woodward, 1892, p. 89, pl. xiv, figs. 11-15, figs. 5, 6 (woodcuts). Chapman, 1908, p. 281, pl.-figs. 2, 3, 5. Idem, 1912, p. 212, pl. xxvii. Id., 1923, p. 42, pl. vii, figs. 11-15.

Observations.—This common Upper Cambrian and Lower Ordovician species is well represented in the present collection. It was originally described from the Skiddaw Slates in England, and the writer has since recorded it from various localities in Victoria, as Loyola (Up. Cambrian); Marong (L. Ordovician-Bendigonian); as well as in erratics of Lower Ordovician black shale in the Permo-carboniferous glacial beds of Wynyard, Tasmania.

The wide distribution of this species may be judged by its occurrence elsewhere. Besides the Skiddavian of England and Wales it has also been found in the equivalent Arenig of the Firth of Clyde in Scotland, as well as in the Arenig of Belgium (Malaise) and the calciferous group (Tremadoc) of Nevada, North America (Gurley).

Referring to the foregoing list of determinations, it will be seen that *Caryocaris wrightii* is fairly well represented in the New Zealand Lower Ordovician.

On Plate 9, fig. 3, is shown a typical, fairly large carapace with an exceptionally strong dorsal fold. Fig. 4 on the same plate shows the trifid caudal appendages, also seen in a Belgian specimen as figured in Jones and Woodward (1892, p. 91, woodcut, fig. 6), and also another from the Upper Cambrian of Loyola, Victoria, by Chapman (1923, pl. xii, fig. 14).

Locality.—No. 112, Loc 3. No. 797, Loc. 12. No. 972, Loc. 4. Nos. 1330, 1332, 1344, Loc. 15. Preservation Inlet, New Zealand. Also from Cape Providence (Park. Coll.).

Horizon.—L 3, L 2, and C 4.

CARYOCARIS MARRII Hicks.

Plate 9. Figs. 5, 6.

Caryocaris marrii Hicks, 1876, *Quart. Journ. Geol Soc.*, Vol. xxxii, p. 138. Jones and Woodward, 1892, p. 92, pl. xiv, figs. 16-18. Chapman, 1903, ? *Rhinopterocaris maccoyi* (Eth. fil), p. 117, pl. xviii, fig. 16. Chapman, 1908. *Caryocaris marrii* Hicks, p. 282, pl. ——, figs. 4, 6 Chapman, 1912, p. 212, pl. xvii.

Observations.—This little phyllocarid is probably the most abundant form in the New Zealand collection. It is of especial interest to note the occurrence here of an example with conjoined valves spread out dorsally, a phase of its compression in the slates comparable with one figured many years ago from a Castlemaine specimen in the National Museum (Chapman, 1903, pl. xviii, fig. 16) under ? *Rhinopterocaris*. In the specimen now figured (Plate 9, fig. 6), sufficient proof is seen that some of the wrinkling of the carapace in these phyllocarids is natural to the organism, and not necessarily a secondary result caused by a lateral crumpling of the rock. In other cases, however, there may exist such an artificial puckering, due to the condition of the surrounding matrix, when of the nature of a phyllite.

The other specimen figured is an elongated, typically crumpled or corrugated form, with a generally concave dorsal margin. The aspect of this fossil (Fig. 5) is probably from the left side, the blunt truncation indicating the abdominal junction, as in *Hymenocaris*.

Distribution.—*Caryocaris marrii* was first recorded from the Arenig Schists of Nanntle, S. Wales. In Australia, localities for this species are the Lower Ordovician rocks of Marong, near Daylesford, and erratics derived from a similar formation from Wynyard, Tasmania.

Locality.—Nos. 108*b*, 147, Loc. 3. Nos. 526, 527, 530, Loc. 17. Nos. 800, 803, Loc. 12. No. 1131, Loc. 10. No. 1140, Loc. 12. No. 1352, No Loc. Preservation Inlet, New Zealand.

Horizon.—L 3, C 4, and C 5.

CARYOCARIS MINIMA, sp. nov.

Plate 9. Fig. 7.

Description of Holotype.—Carapace elongate-lanceolate, sharply acuminate anteriorly, bluntly so at posterior; length three times the height. Dorsal margin gently curved, ventral margin more strongly curving from the anterior region to one-third from the posterior extremity, where it reaches the greatest height; it then curves obliquely upward to meet the posterior at an angle of 20°. Surface relieved by fine, wavy, more or less parallel wrinkles.

Dimensions.—Length, 9 mm.; height at posterior third, 2.3 mm.

Observations.—Several examples of this comparatively minute form of *Caryocaris* may be distinguished on the slabs examined, having the particular characters described for the holotype. Other allied species of *Caryocaris*, such as *C. angusta* Chapman (1903, p. 113, pl. xviii, fig. 10), and *C. oblonga* Gurley (see Chapman, 1908, pls. — fig. 8) differ from the above in having both extremities blunt or gently rounded.

Locality.—No. 524, Loc. 17.

Horizon.—Probably L 3.

Genus *LINGULOCARIS* Salter.

LINGULOCARIS cf. *ACUTA* (Bulman).

Plate 9. Fig. 8.

c.f. *Caryocaris acuta Bulman* (pars). 1931, p. 85, text-fig. 41 (upper figure).

Observations.—There appears to be a general resemblance of Dr Bulman's figure, quoted above, to the present specimen. From its elongate-ovate form it may be referred to the genus *Lingulocaris* Salter.

With regard to the surface ornament the New Zealand specimen agrees very closely with *Lingulocaris siliquiformis* Jones (cf. Jones and Woodward, 1892, pl. xiv, fig. 2) in having a delicate squamiform character.

Bulman's *Caryocaris acuta* came from the Caradocian of Peru, whilst *L. siliquiformis* and other allied species are from the Upper Tremadoc and Lower Lingula Flags of Wales. The present form therefore occupies an intermediate stratigraphic position between these.

Dimensions of Plesiotype of Lingulocaris cf. *acuta.*—Length, 30 mm.; greatest height, 7.5 mm.

Locality.—No. 1142, Loc. 12.

Horizon.—C 4.

Genus *RHINOPTEROCARIS* Chapman.

RHINOPTEROCARIS MACCOYI (Eth. fil.).
Plate 11. Figs. 9, 10, 11.

Lingulocaris maccoyi Etheridge Jur., 1892, pp. 5-8, pl. iv.

Caryocaris curvilatus Gurley, 1896, p. 87, pl. iv, fig. 3; pl. v, fig. 3.

Rhinopterocaris maccoyi (Eth. fil.); Chapman, 1903, pp. 114-117, pl. xviii, figs. 9, 17 (*non* 16).

Observations.—This genus and species is one of the best known of the phyllocarids of the Southern Hemisphere. It is often of comparatively large size and wonderfully well preserved. The carapace is tenuous and reminds one of a neuropterous or other insect wing in its membranous character.

The nomenclature of this species is somewhat involved, and may be summed up as follows:—

McCoy named the phyllocarid in 1861, when writing up the Natural History of Victoria for the International Exhibition, as *Hymenocaris salteri.* This MS. name remained as such for over 30 years, and was twice catalogued in Bigsby's Thesaurus Siluricus, as *Hymenocaris* and *Caryocaris.* J. W. Salter, who had evidently examined a specimen in 1862, did not think it belonged to the genus *Hymenocaris.* R. Etheridge Jur., in 1892, examined specimens of this phyllocarid, which W. W. Froggatt had collected from the Lower Ordovician (Bendigonian) of Bendigo (Sandhurst), Victoria. Other examples were also supplied him by R. A. F. Murray from the Lower Ordovician (Castlemainian) of Baynton's, Campaspe River, Victoria. From the characters being intermediate between *Hymenocaris* and *Caryocaris,* as these specimens showed, Etheridge was induced to place them in the genus *Lingulocaris.* In 1903 the present writer (*loc. supra cit.*), after examining a very large collection of these fossils from Victoria, in the National Museum, recognised details not hitherto known, and instituted for them a new genus, *Rhinopterocaris.* These fossils, for example, showed amongst other characters cephalic appendages, masticatory apparatus, and a short telson with sharp oblique stylet.

The New Zealand occurrence of this phyllocarid is of particular importance, since it is quite as typical there as in Victoria, and is indeed associated with a similar facies including an abundance of *Caryocaris.* Its range in New Zealand is also co-extensive with that in Victoria, namely, from Lancefieldian to Castlemainian.

Of the specimens of *Rhinopterocaris maccoyi* here figured, fig 9, with its double valves slightly displaced, shows unmistakeably

that the carapace is not merely folded, but the valves are loosely conjoined, and in this the genus fundamentally differs from ***Hymenocaris,*** which typically bears the former character.

In fig. 10 the overlapping valves of two individuals show, by the wrinkling occurring in the same direction on valves that are at right angles to one another, that, in this case at least, a mud shrinkage probably took place before the hard setting of the slate.

Locality.—No. 528, Loc. 17. No. 543, Loc. 32. No. 790, Loc. 19. No. 797, Loc. 12. Nos. 813, 830, Loc. 8. Nos. 1140, 1144, Loc. 12. Nos. 1169, 1193, Loc. 9. Nos. 1288, 1333, Loc. 15. Preservation Inlet, New Zealand. No. 18, Cape Providence (Park. Coll.).

Horizon.—L 3 to C 5.

RHINOPTEROCARIS MACCOYI (Eth. fil.) var. *TUMIDA* var. nov.
Plate 10. Fig. 12.

Description.—This variety differs from the large, tenuous, carapaced type-form in having a shorter and higher build. The dorsal margin is gently arched and strongly ridged; the ventral margin broadly curving towards the acute anterior; with the posterior extremity blunt. The texture of the carapace appears to be unusually solid.

Dimensions of type of var.—Length, 17.5 mm.; height, 7.5 mm.

Locality.—No. 790, Loc. 19. Preservation Inlet, New Zealand.

Horizon.—L 2.

RHINOPTEROCARIS BULMANI, sp. nov.
Plate 10. Figs. 13, 14.

Caryocaris acuta Bulman (pars.). 1931, p. 85, text-fig. 41 (lower figure).

Observations.—Dr Bulman has figured two specimens under the name of *Caryocaris acuta.* Judging from the evidence derived from a study of a very extensive series of phyllocarids from Australian and New Zealand Ordovician rocks, I have ventured to suggest that the two figures given by Dr Bulman may not be congeneric. His upper figure I have here referred to ***Lingulocaris,*** with its elongated boat-shaped carapace, and have tentatively connected a New Zealand form as con-specific. The lower figure given by Bulman, although somewhat fore-shortened from its original length by slate rippling, is too deep in the body for *Caryocaris*, and would seem to be more closely allied to ***Rhinopterocaris*** as met with in Australia and New Zealand. It is appropriate therefore to name this form after Dr Bulman. His figured specimen has a length of 8.6 mm., whilst the New Zealand specimen (fig. 13) measures 12.6 mm.

Another example from New Zealand (fig. 14), somewhat distorted, has a length of 4.7 mm.

Locality.—No. 526 (fig. 13), Loc. 17. No. 108*a* (fig. 14), Loc. 3. Preservation Inlet, New Zealand.

Horizon.—L 3.

Explanation of Plates.

Plate 9.

Fig. 1. *Hymenocaris bensoni*, sp. nov. Carapace and abdominal segments. No. 139. Loc. 3. Hor. L 3. Holotype. × 3½.

Fig. 2. *Hymenocaris lepadoides*, sp. nov. Carapace and abdomen. No. 825. Loc. 8. Hor. B 1, low. Holotype. × 2.

Fig. 3. *Caryocaris wrightii*, Salter. Carapace of large example. No. 112. Loc. 3. Hor. L 3. Plesiotype. × 4½.

Fig. 4. *Caryocaris wrightii*, Salter. Trifid caudal appendages. No. 526. Loc. 17. Hor. ? L 3. Plesiotype. × 3.

Fig. 5. *Caryocaris marrii*, Hicks. Typical carapace. No. 108*b*. Loc. 3. Hor. L 3. Plesiotype. × 7.

Fig. 6. *Caryocaris marrii*, Hicks. Dorsal view of conjoined valves. No. 803. Loc. 12. Hor. C 4. Plesiotype. × 2.

Fig. 7. *Caryocaris minima*, sp. nov. Carapace. No. 524. Loc. 17. Hor. L 3. Holotype. × 3.

Fig. 8. *Lingulocaris* cf. *acuta* (Bulman) (pars.). Carapace. No. 1142. Loc 12. Hor. C 4. Plesiotype. × 2.

Plate 10.

Fig. 9. *Rhinopterocaris maccoyi* (Eth. fil.). Two valves opposed and reversed. No. 543. Loc. 32. Hor. C 5. Plesiotype. × 2.

Fig. 10. *Rhinopterocaris maccoyi* (Eth. fil.). Separate valves of two individuals. No. 1193. Loc. 9. Hor. B 1, low. Plesiotype. × 2.

Fig. 11. ? *Rhinopterocaris maccoyi* (Eth. fil.). Carapace with cercopods. No. 1320. Loc. 15. Hor. L 2. Plesiotype. × 2.

Fig. 12. *Rhinopterocaris maccoyi* (Eth. fil.), var. *tumida*, var. nov. No. 790. Loc. 19. Hor. ? L 7. Holotype of var. × 2.

Fig. 13. *Rhinopterocaris bulmani*, sp. nov. No. 526. Loc. 17. Hor. ? L 3. Plesiotype. × 3.

Fig. 14. *Rhinopterocaris bulmani*, sp. nov. No. 108*a*. Loc. 3. Hor. L 3. Plesiotype. × 7.

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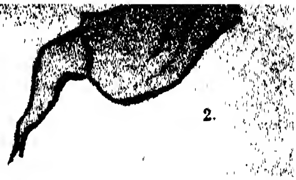
1.



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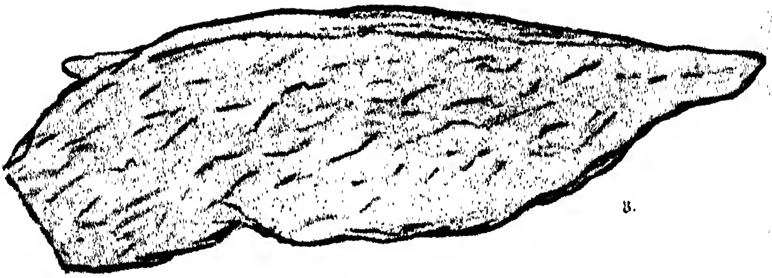


3.

4.

6.

FIG. 1.—*Hymenocaris bensoni*, sp. nov. Carapace and abdominal segments. No. 139. Loc. 3. Hor. L 3. Holotype. × 3½.

FIG. 2.—*Hymenocaris lepadoides*, sp. nov. Carapace and abdomen. No. 825. Loc. 8. Hor. B 1, low. Holotype. × 2.

FIG. 3.—*Caryocaris wrightii*, Salter. Carapace of large example. No. 112. Loc. 3. Hor. L 3. Plesiotype. × 4½.

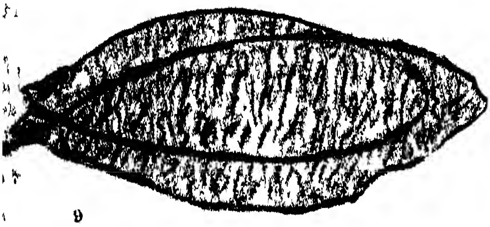
FIG. 4.—*Caryocaris wrightii*, Salter. Trifid caudal appendages. No. 526. Loc. 17 Hor. ? L 3. Plesiotype. × 3.

FIG. 5.—*Caryocaris marri*, Hicks. Typical carapace. No. 1085. Loc. 8. Hor. L 3. Plesiotype. × 7.

FIG. 6.—*Caryocaris marri*, Hicks. Dorsal view of conjoined valves. No. 803. Loc. 12. Hor. C 4. Plesiotype. × 2.

FIG. 7.—*Caryocaris minima*, sp. nov. Carapace. No. 524. Loc. 17. Hor. L 3. Holotype. × 3.

FIG. 8.—*Lingulocaris* cf. *acuta* (Bulman) (pars.). Carapace. No. 1142. Loc. 12.



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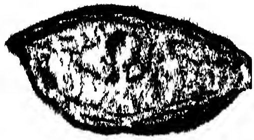

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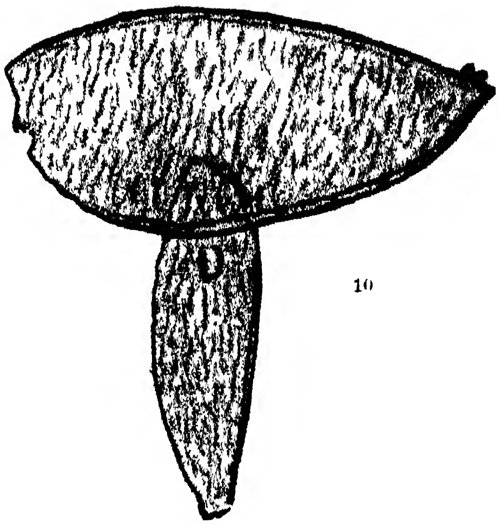

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FIG. 9.—*Rhinopterocaris maccoyi* (Eth. fil.). Two valves opposed and reversed. No. 543. Loc. 32. Hor. C 5. Plesiotype. × 2.

FIG. 10.—*Rhinopterocaris maccoyi* (Eth. fil.) Separate valves of two individuals. No. 1193. Loc. 9. Hor. B 1, low. Plesiotype. × 2.

FIG. 11.—?*Rhinopterocaris maccoyi* (Eth. fil.). Carapace with cercopods. No. 1320. Loc. 15. Hor. L 2. Plesiotype. × 2.

FIG. 12.—*Rhinopterocaris maccoyi* (Eth. fil.), var. *tumida*, var. nov. No. 790. Loc. 19. Hor. ? L 7. Holotype of var. × 2.

FIG. 13.—*Rhinopterocaris bulmani*, sp. nov. No. 526. Loc. 17. Hor. ? L 3. Plesiotype. × 3.

FIG. 14.—*Rhinopterocaris bulmani*, sp. nov. No. 108a. Loc. 3. Hor. L 3. Plesiotype. × 7.

On some Brachiopods from the Ordovician of Preservation Inlet, New Zealand.

By FREDERICK CHAPMAN, A.L.S., F.G.S., F.R.S.N.Z.
(Commonwealth Palaeontologist).

[*Read before the Otago Institute, 12th September, 1933; received by the Editor 30th September, 1933; issued separately, September, 1934.*]

INTRODUCTION.

A SMALL collection of minute oboloid brachiopods has been submitted to me for determination by Prof. W. N. Benson. The fossils occur on two small slabs of black slate, in groups of three separate valves. The surfaces of the slabs are counterparts of one another.

On all of the valves the concentric ornament is shown, so that it is most likely that they represent the corresponding valves of each of the three specimens.

These minute fossils may be regarded as belonging to the atrematous obolid form, *Leptobolus*, having a terminal foramen, thin shell, and feeble divergent septa, of which traces only are seen in one or other of the specimens.

In addition to the form above mentioned there is another, badly preserved, brachiopod, tentatively referred to cf. *Obolus* sp., but practically a cast. It is associated on the same slab with *Bryograptus consobrinus*.

DESCRIPTION OF SPECIMENS.

Class *BRACHIOPODA*

Order *ATREMATA*

Fam. *OBOLIDAE*

Genus *LEPTOBOLUS*, James Hall

LEPTOBOLUS NOVAEZELANDIAE, sp. nov.

Plate 11. Figs. 1, 2, 3, 4.

Description of Syntypes.—Valves on opposite faces of slabs (marked 2A and 2B). Shell substance thin, corneous and glistening. Valves roundly ovate, with the apical region slightly prominent and subacute. Anterior margin widely rounded; cardinal or posterior margin flattened on either side of the foramen, which is conspicuous.

Shell-surface ornamented with closely set, wavy growth-lines, about 20 in the space of a millimetre. These growth-lines are somewhat tegulate or over-lapping. The shell-surface also shows traces of excessively fine radii, whilst the anterior margin shows radial

fracture lines due to excessive crushing. Figs. 1 and 2 appear to represent the pedicle valve, whilst figs. 3 and 4 are probably of the dorsal valve, with divergent furrows.

Dimensions.—Length, 3 mm.; width, 3.2 mm.

Observations.—Several related species of this genus may be compared with the present form. *Leptobolus insignis*, J. Hall (1872, p. 227, pl. vii, fig. 17), from the Utica Slate, shows a similar roundly ovate outline, and, moreover, is finely striate. It differs, however, in not having undulate growth-lines. The present writer has also described a species of *Leptobolus* from Heathcote (Middle Cambrian) as *L. truncata* (Chapman, 1917, p. 93, pl. vi, figs. 3, 3*a*), but this differs in the trigonal outline of the valves.

Locality.—Nos. 2A, 2B, Loc. 26. Morning Star Mine, Preservation Inlet, N.Z.

Horizon.—Top of L 3 or lower part L 2.

Genus *OBOLUS* Eichwald.

cf. *OBOLUS* sp.

Plate 11. Fig. 5.

Observations.—The specimen provisionally referred to this genus has evidently been crushed. It represents a decorticated transversely ovate valve, probably dorsal, and shows the divergent furrows of an obolid, whilst there are traces on the anterior margin of widely spaced furrows.

Dimensions.—Length of valve, 3.66 mm.; width, 5 mm.

Locality.—No. 770, Loc. 19. Preservation Inlet, N.Z.

Horizon.—From about the same horizon as the foregoing slab with *Leptobolus novaezealandiae*, viz., top of L 3 or lower part of L 2, associated with *Bryograptus consobrinus*. The Lancefieldian horizons are given in a reversed sequence to deposition, following T. S. Hall in his early work.

Explanation of Plate.

Plate 11.

Fig. 1. *Leptobolus novaezelandiae*, sp. nov. No. 2A. Loc. 26. Morning Star Mine, Preservation Inlet, New Zealand. Pedicle valve. Syntype. × 17.

Fig. 2. Ditto. Sketch showing salient characters. × 4.

Fig. 3. *L. novaezelandiae*, sp. nov. No. 2B. Loc. 26. Morning Star Mine, Preservation Inlet, New Zealand. Dorsal valve. Syntype. × 17.

Fig. 4. Ditto. Sketch showing salient characters. × 4.

Fig. 5. cf. *Obolus* sp. No. 770. Loc. 19, near to that of above species. Cast of dorsal valve (badly preserved). × 3.

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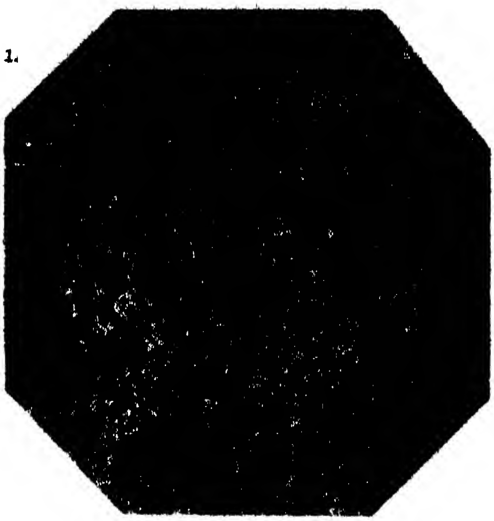

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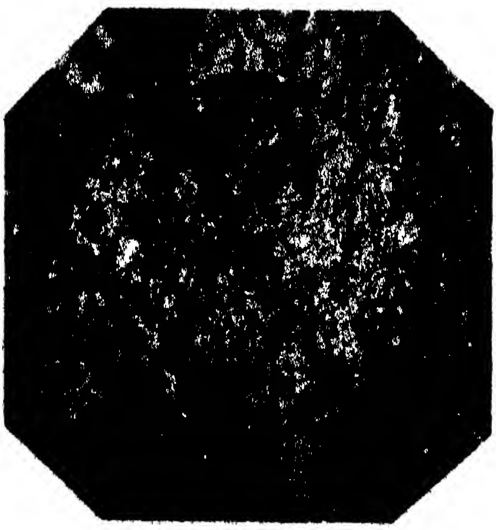

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Fig 1.—*Leptobo* , sp nov No. 2A. Loc. 26. Morning Star Mine, ealand. Pedicle valve. Syntype × 17
Fig. 2. — ketch showing salient characters. × 4.
Fig. 3.—*L.* *elandica*, sp. nov. No. 2B. Loc. 26. Morning Star Mine, Preservation Inlet, New Zealand. Dorsal valve. Syntype. × 17.
Fig. 4.—Ditto. Sketch showing salient characters × 4
Fig. 5.—cf. *Obolus* sp. No. 770. Loc. 19, near to that of above species Cast of dorsal valve (badly preserved). × 8.

Descriptions of Fossil Fish from New Zealand

By FREDERICK CHAPMAN, A.L.S., F.G.S., F.R.S.N.Z.
(Commonwealth Palaeontologist).

[*Read before the Otago Institute, 14th November, 1933; received by the Editor, 30th November, 1933; issued separately, September, 1934.*]

INTRODUCTORY NOTE.

FOR the opportunity of describing these exceptionally interesting specimens I am indebted to Professor W. N. Benson, D.Sc., Otago University, Dunedin.

The new species of *Portheus* shows a very high geological range for that genus, which, so far, has been limited to the Neocomian up to the Senonian, whereas in New Zealand it is found in beds which may extend into basal Eocene.

The occurrence of *Eothyrsites* in the Burnside marls, especially in its relationship to *Thyrsitocephalus,* helps to confirm the horizon as Oligocene. This is further supported by the foraminiferal fauna found in the same stratum.

All type specimens have been placed in the collections of the Geology Department, Otago University.

DESCRIPTIONS OF THE FOSSILS.

PISCES

Sub-Class *TELEOSTEI*

Fam. *ICHTHYODECTIDAE*

Genus *PORTHEUS* Cope

PORTHEUS DUNEDINENSIS, sp. nov.

Plate 12, fig. 1.

Description.—Type specimen representing the larger part of the cranium with supra-occipital and lower jaws, the anterior vomerine portion wanting.

The cranium measures about 18 cm. in height; 17 cm. in length; and about 12 cm. in width.

The cranial region, on the left side, shows the bones of the frontal region much crushed, with the pre-frontal and ethmoid truncated by fracture.

The ossified sclerotic plates are well preserved; the bony ring has a diameter of 43 mm., with the plates measuring 15 mm. in depth.

Maxilla, in widest part, measuring 32 mm. Total length of maxilla as preserved, 13.5 cm. Dentary series with backwardly curved and conical teeth, varying from 5 to 9 mm. in length, and plicate near the base. Sixteen of these teeth are preserved, but the entire series for the ramus probably numbered about 36. Premaxilla wanting. Mandibular ramus strong and deep, at the widest part 4.3 cm.

Right side of the cranium shows the frontal bones much crushed, the sclerotic plates present, but obliquely displaced. Maxillary with only six teeth preserved. Mandibular ramus 4.7 cm. deep.

Matrix of Specimen.—The rock in which the cranium of the fish was embedded is a hard, marly greensand, of a greenish grey colour. Washings of the rock yield a residue which is almost purely glauconitic. Amongst the glauconite casts of foraminifera were recognised, infillings of *Globigerina*, *? Rotalia* and a plane-convex rotaline form which may be *Globotruncana* (a Cretaceous genus).

Observations.—The present species, *Portheus dunedinensis*, was, when complete, rather more than half the length of *Portheus molossus* Cope (1875, pp. 184, 194, fig. 8 woodcut, pls. xxxix-xli; pl. xliv, figs. 5, 10, 11; pl. xlv, figs. 9-11). In the latter the cranium is higher and the teeth of the maxilla are not curved at the apex as in *P. dunedinensis.*

In its general dimensions *P. dunedinensis* compares very closely with *Portheus australis* (A. S. Woodward, 1894, pp. 44, pl. ix, figs. 1, 1*a*) from Clutha Station, near Hughenden, Queensland. These Cretaceous beds, with an accompanying fauna of reptilian remains, are now referred to the Tambo Series, equivalent to the Upper Albian of Europe. The teeth in the New Zealand species, however, are stouter and broader at the base, and are less regularly spaced on the maxilla, as compared with the Queensland *P. australis*, in which they are fairly evenly arranged.

E. T. Newton (1877, p. 511, pl. xxii, fig. 13) has described *Portheus daviesii*, from the Lower Chalk (Turonian) near Maidstone, Kent, but here the teeth of the maxilla are in a shorter series, and are more slenderly conical than in *P. dunedinensis.*

The same author also described another species of the genus as *Portheus gaultinus* (Newton, 1877, p. 512, pl. xxii, figs. 1-12 and woodcut), from the Albian (Gault) of Folkestone, Kent. This form differs from the New Zealand species in the much smaller size and lighter build of the maxillary, and in the generally longer and slenderer teeth.

Portheus lewesiensis (Agassiz), which was described by that author under the genus *Hypsodon* (1843, p. 99, pls. xxv *a*, xxv *b*), has a very heavy type of mandible, and the teeth are correspondingly strong, short, conical, and broad at the base.

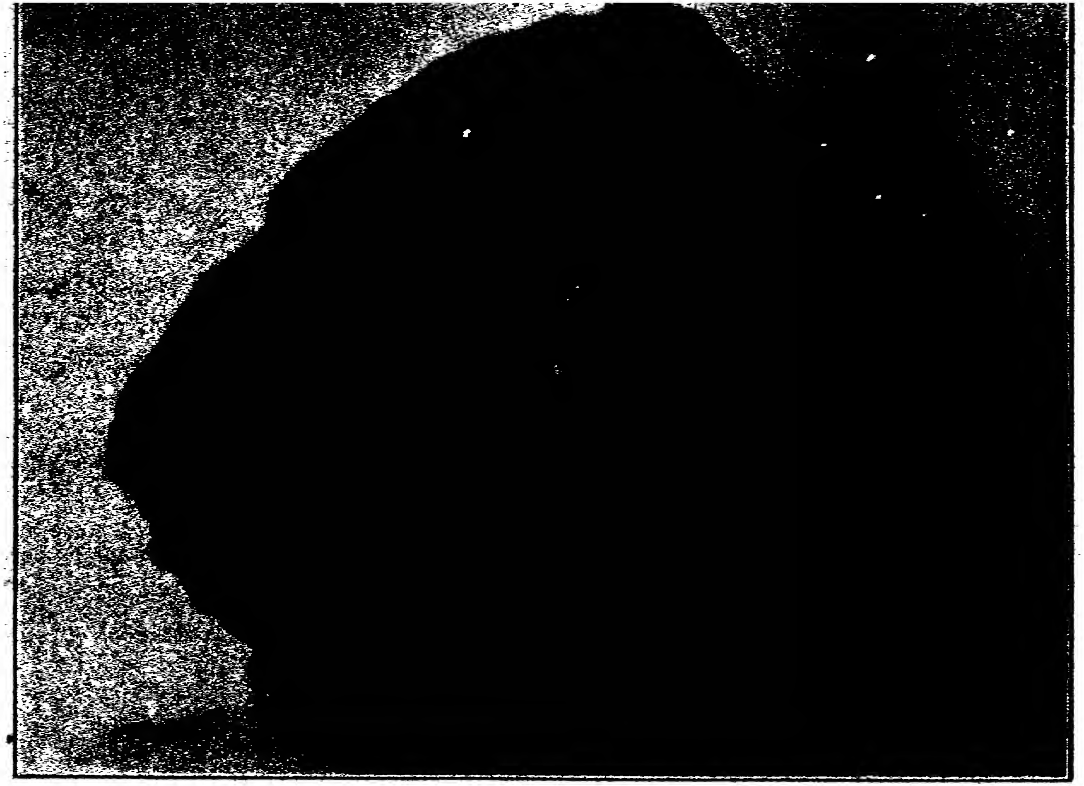
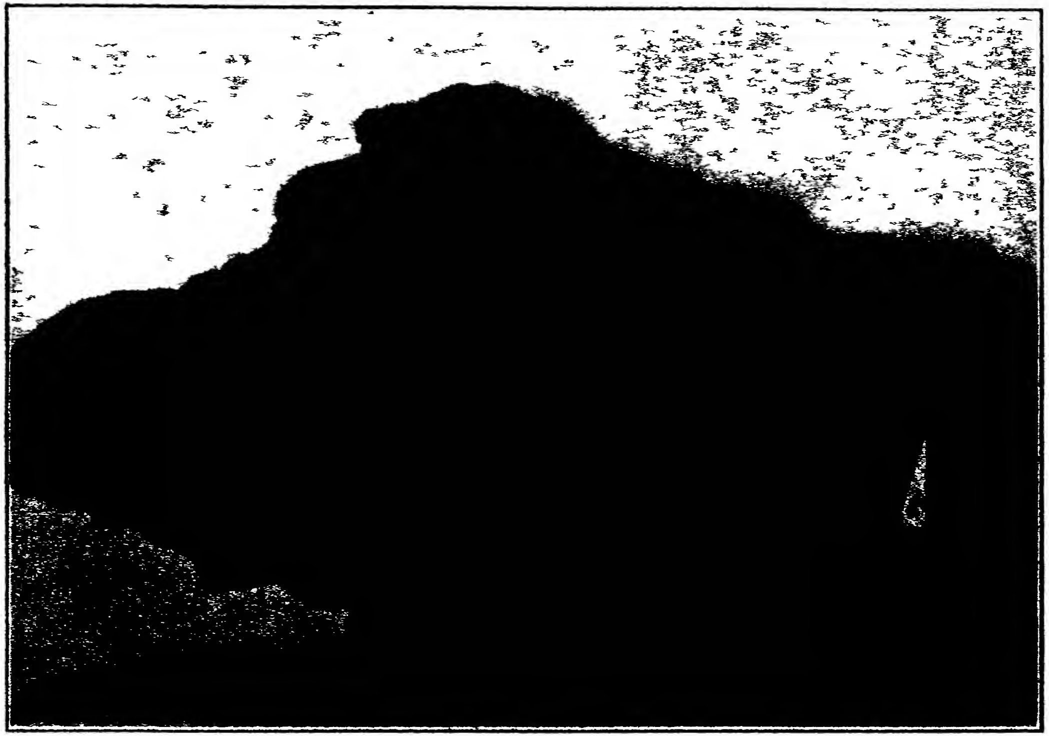


FIG. 1.—*Portheus dunedinensis*, sp. nov. Left side of cranium. Abbotsford, near Dunedin, N.Z. Of probable Palae-eocene or Danian age. Holotype. Half nat. size.



'IG 2 —*Eothyrsites holosquamatus* gen et sp nc S udstone wit vertebrae rays of dorsal fin ventral fin and edian part body Marl pit Burnside Green Island N Z Uppe Oligocene Syntype Half nat size

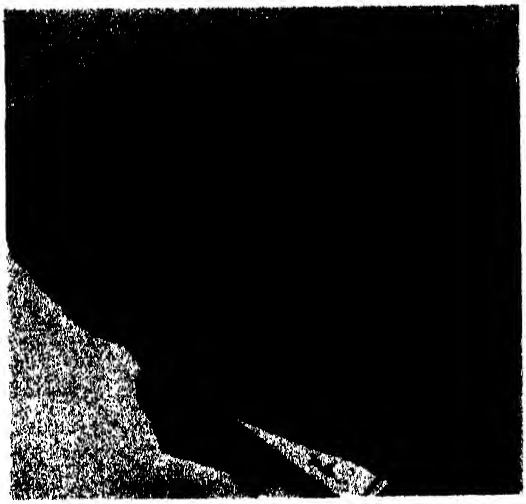


FIG. 3.—*Eothyrsites holosquamatus*, gen. et sp. nov. Side of cranium with part of mandible and teeth. Marl-pit, Burnside, Green Island, near Dunedin, N.Z. Upper Oligocene. Syntype. Two-thirds nat. size.

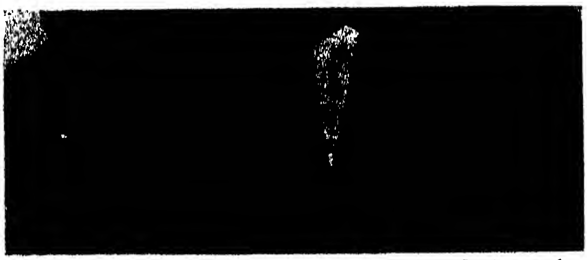


FIG. 4.—*Eothyrsites holosquamatus*, gen. et sp. nov. Pectoral fin. Marl-pit, Burnside, Green Island, near Dunedin, N.Z. Syntype. Two-thirds nat. size.

FIG. 5.—*Eothyrsites holosquamatus*, gen. et sp. nov. Same as Fig. 2, showing strong character of squamation, with vertebrae. Enlarged one and a-half times.

Locality and Horizon.—The above-described fossil was found in the glauconitic mudstone at Abbotsford, near Dunedin. It occurs about 500 feet above the horizon which contains a Wangaloan fauna, referred to by New Zealand stratigraphists as either Palae-eocene or Danian.

From the previous records of the genus *Portheus* it is a distinctly Cretaceous genus. The Abbotsford bed, therefore, can hardly be regarded as younger than Danian

Fam. *GEMPYLIDAE.*

Genus *EOTHYRSITES*, gen. nov. Chapman, 1933.

Generic Characters.—Body moderately elongated; form probably near that of the recent *Thyrsites atun,* but somewhat deeper. Abdominal vertebrae with diameter of centrum more than half the length, instead of less, as in *Thyrsites.* Surface of body almost covered with moderately large cycloid scales. In *Thyrsites,* a degenerate genus, these scales are confined to the lateral line. Pectoral fins long and narrow, as in *Thyrsites*

EOTHYRSITES HOLOSQUAMATUS sp. nov.

Plate 13, fig. 2; plate 14, figs. 3-5.

Description of Genotype and Holotype- An imperfect fish, consisting of three portions.

1. A slab, 24 x 12 cm., showing 6 vertebral bones, rays of the dorsal fin, ventral fin, and squamation of the median part of the body.

2. A crushed slab, 14 x 9 cm., showing crushed facial bones (? quadrate and pterygoid), part of mandible with teeth, and on the opposite face of slab, the preopercular.

3. Fish remains, 13 x 5 cm. on slab of mudstone, with a complete left pectoral fin.

Vertebrae.—The series of abdominal vertebrae shown here are of much the same contour as those in the recent Barracouta (*Thyrsites atun*), but on the whole much stouter and heavier. One of these centra has a length of 27 mm. and a maximum diameter of 19 mm . in the middle of the centrum it narrows down to 12 mm. The rounded border of the adjacent centra indicates the former existence of a distinct cartilage pad, as in *Thyrsites.*

Pectoral Fin.—Narrow, slender, and only slightly curved; the proximal end shows a distinct articulating surface for attachment to the brachial. The rays are bony, narrow, and closely fasciculated The length of the fin is 70 mm., and the greatest width 21 mm

Teeth.—These number 5 and are arranged along part of the maxilla in an even series in a line measuring 16 mm. They are slender towards the tip, which is inwardly curved; they widen rapidly to the base, and in the alveolar socket are broad and cylindrical, as seen where a tooth has fallen out.

Length of teeth, 4 mm.; total length, with alveolar base, 6 mm.; width near base, 1 mm.

Squamation.—One of the highly important and interesting structures in *Eothyrsites* is the more or less complete scaly armour of the body. So distinct is this feature that, on first acquaintance with the specimens, it appeared as if the relationship to *Thyrsites* might be questioned. Upon examining the skin of a living Barracouta, it was seen that cycloid scales, precisely of the same character, and often of the exact dimension, of those in the fossil form *Eothyrsites,* were present along the lateral line of the fish, forming a close protective armature. It therefore seems entirely reasonable to suppose that in *Eothyrsites* we have an Oligocene form ancestral to the living *Thyrsites* and other related and almost scale-less fishes, as *Lepidopus.* In the case of *Thyrsites* a degeneration of the skin armature has taken place, the skin still being marked, however, by scale-like areolae, in which a vestige of the earlier scaly character has been retained for the protection of the slime canals. The average diameter of the scales in *Eothyrsites* is 4 mm., although in some cases they measure as much as 7 mm.; in *Thyrsites* the scales measure from 1.5 to 3 mm. The scales in *Eothyrsites* appear to be strengthened by ganoine and more or less calcified, whereas in *Thyrsites* they are thin and flexible.

The occurrence of the definite system of cycloid scales along the lateral line in the living *Thyrsites* does not appear to have been recorded by any previous writers excepting McCoy (1879), who says "greater part of the body naked" (loc. cit. p. 19).

Observations.—In its skeletal form the genus *Thyrsitocephalus* represented by *T. alpinus* vom Rath, resembles *Eothyrsites.* The former fossil, however, does not show the squamose characters, so that it seems safer to institute the new genus for the New Zealand specimen. Vom Rath's type of *Thyrsitocephalus* came from the Oligocene of Canton Glarus, Switzerland (Rath, 1859, p. 114, pl. III, fig. 4).

Locality and Horizon.—Marl Pit, Burnside, Green Island, near Dunedin, New Zealand. Upper Oligocene.

Note.—In my monograph on the Cretaceous and Tertiary Foraminifera of New Zealand (Chapman 1926, p. 16) I gave the horizon of the foraminifera of the Burnside marl as "Upper Eocene probably)." From a recent examination of the recorded fauna, together with additional foraminifera found by Miss Crespin and myself in the matrix with the fish skeleton, we find that it exactly agrees in the faunal horizon of the Goon Nure Bore, Gippsland, Victoria, below 2020 feet, which we have referred to the Upper Oligocene.

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EXPLANATION OF PLATES.

Plate 12.

Fig. 1. *Portheus dunedinensis*, sp. nov. Left side of cranium. Abbotsford, near Dunedin, N.Z. Of probable Palae-eocene or Danian age. Holotype. Half nat. size.

Plate 13.

Fig. 2. *Eothyrsites holosquamatus*, gen. et sp. nov. Slab of mudstone with vertebrae, rays of dorsal fin, ventral fin, and scales of the median part of body. Marl-pit, Burnside, Green Island, near Dunedin, N.Z. Upper Oligocene. Syntype. Half nat. size.

Plate 14.

Fig. 3. *Eothyrsites holosquamatus*, gen. et sp. nov. Side of cranium with part of mandible and teeth. Marl-pit, Burnside, Green Island, near Dunedin, N.Z. Upper Oligocene. Syntype. Two-thirds nat. size.

Fig. 4. *Eothyrsites holosquamatus*, gen. et sp. nov. Pectoral fin. Marl pit, Burnside, Green Island, near Dunedin, N.Z. Syntype. Two-thirds nat. size.

Fig. 5. *Eothyrsites holosquamatus*, gen. et sp. nov. Same as Fig. 2, showing strong character of squamation, with vertebrae. Enlarged one and a-half times.

Plant Succession on the Oreti River Sand Dunes

By Margaret C. Logan, M.A., and J. E. Holloway, D.Sc.,
University of Otago.

[*Read before the Otago Institute, 13th June, 1933; received by Editor, 20th June, 1933; issued separately, September, 1934.*]

The area of sand dunes considered here lies as a fringe along the eastern bank of the Oreti River, near where it runs into the New River Estuary at Invercargill (Map, Fig. 1). It is swept by the frequent south-west and westerly winds. The climate is prevailingly cool and damp, with many overcast days. The special problem attacked in this paper is that of plant succession on these dunes, the presence of wind-excavated dune-hollows in various stages of development and of stabilisation presenting a useful opportunity for such a study. These hollows all run in an easterly direction, more or less at right angles to the river bank, and are initiated by breaches made in the dune front in flood time. The account here given is based upon data gathered during a number of visits paid by both authors to the locality.

We wish to thank Dr H. H. Allan, of the Plant Research Station, Palmerston North, for identifying a number of the species here dealt with. This paper is based upon a thesis which was presented by the first-named author as part requirement for the degree of M.A. in the University of New Zealand. Both authors are, however, responsible for the paper in its present form.

Notes on the Environmental Factors Operating in the Area Dealt With.

For details concerning the rainfall and its distribution throughout the year, the number of rainy days, the range of temperature, cloudiness, etc., reference should be made to the Meteorological Department's records for Invercargill. In brief, it can be stated that all of these factors are conducive to a more or less uniformly low rate of evaporation from the soil surface and from the transpiring surface of the plants. There will, of course, be periods of dry, clear weather of varying duration, during which, at least in the summer, the temperature of the surface layer of the sand dunes will be high and the humidity of the air in contact with the sand surface will be low, with the result that at such times, in spite of the fact that the winds are mainly cool, moisture-laden ocean winds, evaporation will be greatly increased.

The average number of days per year on which winds blow from the southward and westward is 170. The coastal sand dunes show a strongly marked tendency to move in an easterly direction, and the drifting of the sand and the formation of new hollows in the line of dunes plays an important part in determining the nature of the plant covering.

In the case of the youngest hollows, the soil is practically pure sand which is of a fine texture and is readily blown by the wind. The incoming of humus depends altogether upon the development of a plant covering upon this soil. Thus the pioneer species have special edaphic conditions to face. As to the soil moisture, it is a well-known fact that on coastal sand dunes, in spite of the absence of humus with its water-holding abilities, and also even under conditions of strong surface evaporation, the layers of sand below the uppermost loose dry stratum are moist and firm, owing to the capillary movement of water from below. One of the most important points to be considered in the development of a plant covering upon the floor of a new hollow is the loose dry shifting nature of the surface layer, since the seedlings of the pioneer species will have to get their roots down quickly through this to the moisture below, and the plants will at all times have to cope with the burying power of the wind-driven sand. When once these pioneer species have become well established, however, they will tend to consolidate the sand surface and to provide humus and so to act as seed beds, so that additional species will come in and in turn play their part in the succession. Even in the case of well-turfed hollows there will, however, be a tendency for sand to be blown on to the floor from the less closely covered sides.

The dunes considered in this paper have been very little, if at all, interfered with by man or by grazing animals. We have observed traces of rabbits, but to so small an extent that it can confidently be stated that rabbits have had no effect upon the nature of the plant succession.

During such times as the river is in flood, breaches are occasionally made in the dune front by the undercutting effect of the river, followed by the falling in of the sides of the breach so made. Such a breach is the initial stage in the formation of a new dune hollow (Fig. 2), its subsequent enlargement being due to the blowing out of the loose dry sand. The power of the wind to erode and shift the sand is clearly evidenced by the blown out hollow shown in Fig. 5.

THE DUNE VEGETATION WITH SPECIAL REFERENCE TO SUCCESSION.

(a) General.

As has been stated above, all stages in the erosion of dune hollows and their subsequent stabilisation by a plant covering are to be seen in this area, up to the stage at which the large, wide, mature hollows are completely covered by a dense association of turf-forming species with *Poa caespitosa* and *Scirpus nodosus* tussocks, and with a *Podocarpus totara* shrubbery pushing its way down the hollow from the eastern upper end (Fig. 6). The hollows are separated from one another by flat ridges of varying width and of a uniform height of about 10-20 feet. These elevated portions of the dune area are covered closely with the *Poa* tussocks, but the plant covering between the tussocks is for the most part less close, and comprises fewer species, than in the hollows. However, the covering on these ridges is a comparatively stable one. The succession described below

refers only to what takes place on the floor and sides of the hollows. On the drier ridges the succession will be of a somewhat different nature, and will be determined largely by the spread of species from the hollows.

When once the above-mentioned, practically mature stage in the succession in the old hollows has been reached (Fig. 6), it might appear to be unlikely that the wind would erode it again. The hollow is now wide and relatively shallow, so that the wind passes over it, rather than being drawn through it as through a funnel as it is in the case of the younger, narrower hollows. However, all the hollows in this area, mature as well as young, are very narrow at their lower end where they approach the river bank, this lowermost end being blocked by a more or less massive barrier of consolidated sand, covered by vegetation, which has accumulated there owing to a combination of wind and river action. This is well seen in the hollow shown in Fig. 4, where already two new breaches have been made in this barrier. Even in the case then of the oldest and widest hollows it is conceivable that by the making of a breach in this way wind erosion of the close turf and tussock covering could begin again at the lower end of the hollow and could steadily proceed up it. For example, this was found to be taking place in the hollow shown in Fig. 5, which is intermediate in size and age to those shown in Figs. 4 and 6, whose upper eastern end had been completely blown out, and whose floor was for the most part strongly eroded.

(b) The Pioneer Species.

The small densely growing cushion-former *Raoulia australis* var. *albosericea* was found to be the first comer on the floor of new breaches made in the dune front.* For example, in the case of the very young breach shown in Fig. 2 a few small individuals of this species had already made their appearance on the uneven bare floor. On another similar but slightly older breach no plants of any kind were observed on the floor on the occasion of our first visit to the locality, but some seven months later we were able to find a few seedlings of both the *Raoulia* and of *Colobanthus Muelleri.* That this *Raoulia* plays a conspicuous part in the early stages of colonisation is shown also by the fact that it is commonly to be found in isolated cushions (never large, but of various sizes up to 8in in diameter) on either a loose sandy surface such as the bare sides of a hollow, or on a firm, bare, wind-swept surface. It was plentifully present, for instance, on portions of the bare,' hard floor of the highly eroded hollow shown in Fig. 5. Fig. 3 is a quadrat made at a selected place in this last-named hollow, and shows the patch forming individuals of the *Raoulia* drawn to their relative sizes. The only other species present here was *Colobanthus Muelleri*,

* With regard to this plant Dr Allan states: "It is identical with the coastal plant of Wellington, and very close indeed to the Volcanic Plateau plant that Colenso described as *R. albosericea* (*T.N.Z.I.:* 20, 1887, p. 195). I am inclined to place them all together as a compound variety, using Colenso's name."

represented by a few scattered individuals. This latter species is a very small tuft plant, less than one inch high, which does not form patches, and is too small to play a part of any significance in consolidating the sand surface. As is referred to in detail below, *Raoulia australis* var. *albosericea* possesses morphological characters which obviously fit it for withstanding the severe conditions of its station on the dunes. The part that it plays in preparing the way for other early colonising species is probably insignificant, except when, as we found only rarely to be the case, it is present in considerable quantity (Fig. 3), and then it will certainly help to hold the drifting sand. Its cushions are comparatively small, and are moreover so dense that wind-driven seeds of other species will rarely find a lodgment on them. As a matter of fact, most of the cushions examined by us did not show the presence of other species on them. Not a few seedlings of this *Raoulia* of different ages were observed by us in several bare localities, so that it is clear that germination and establishment takes place fairly freely.

Passing from the consideration of this species, there is no doubt that the following early comers play an important part in the formation of a close plant covering on bare sand, viz., *Hydrocotyle americana* var. *heteromeria*, *Raoulia australis* var. *apice-nigra*, and *Acaena microphylla* var. *pauciglochidiata*, and, to a somewhat less degree, *Epilobium nerterioides* var. *minimum*. These are all quick growing, copiously branching, low creeping herbs, rooting at the nodes, whose mat growth-form is well fitted to consolidate the sand in their immediate neighbourhood. These species are true pioneers, albeit for the most part on such parts of the floor of young hollows as are firmer than those on which *Raoulia australis* var. *albosericea* can gain a footing. From such places they extend outwards into looser sand, commonly two or more of them growing intermixed, so giving rise to a plant covering which is the initial stage in the formation of a turf. These species, besides serving to anchor the surface layers and consolidate them, will provide a certain amount of humus by their own progressive decay, and will catch wind-driven seeds of other species, and so act as a seed bed for the latter.

(c) Other Incoming Patch-forming Species.

On the floor of the hollow shown in Fig 4 there is no bare sand. The floor is covered with a dense turf on which the large tussock grass *Poa caespitosa*, and, in damper parts, the sedge *Scirpus nodosus* also, is established. The plant covering of this hollow may be taken as typical of that of all the hollows in this area of similar age. The above-mentioned four creeping species are all abundantly present, and can be regarded as constituting the main element in the turf. Small isolated plants of *Colobanthus Muelleri* are common in the turf, and there are also occasional small cushions of *Raoulia australis* var. *albosericea*. Other creeping species which are also more or less commonly interspersed in the turf are *Helichrysum filicaule* and *Mentha Cunninghamii*, and, in addition, some or other of the species referred to below as playing a more or less important part in the hollows.

Three patch-forming species of *Gunnera* must next be mentioned, viz., *G. monoica* var *albocarpa*, *G. arenaria*, and *G. Hamiltoni*. The first-named is to be found not infrequently intermixed with the other turf formers, although in damp places it may become dominant. *G. arenaria* is much less commonly present, being restricted to a few localities, although it is abundant on the Sandy Point Domain on the opposite (western) side of the Oreti River. *G. Hamiltoni* (Fig. 8) is known to be confined to the shores of Foveaux Strait. It is more robust in habit than any of the other New Zealand members of the genus, and in these dune hollows forms very dense and extensive patches, usually to the exclusion of all other plant species, sending out fast-growing stolons which quickly consolidate bare sand (Fig. 7). It forms a conspicuous feature in the plant covering of several of the hollows. As with all *Gunnera* species, it needs a certain degree of dampness in the substratum, and is to be found especially on the more shaded western sides of the dune hollows, from whence it spreads on to and across the floor. On account of its rapid growth and dense robust patch-forming habit it is a most efficient stabiliser of a sandy surface, resisting the eroding effect of wind more than any of the other turf-forming plants. It is, however, apparently not a true pioneer species.

Two species which in these hollows have adopted the character of patch-formers are *Pimelea Lyallii* and *Gentiana saxosa*. The former is typically a semi-prostrate, sub-shrubby, much-branched plant which is commonly present along the coast of Southland. It is fairly common in dune hollows, and comes in at a comparatively early stage in the consolidation of the hollow. Both it and the Gentian are able to establish themselves on the unstable sides of hollows, and in this station are of especial importance. By its quick growth *Pimelea* keeps the ends of its straggling branches above accumulating sand, and by the copious development from them of adventitious roots it consolidates the sand around itself. Such a plant finally appears above the surface as a low-growing flat patch which may be up to 3 feet in diameter, thus assuming the role of a turf former. *Gentiana saxosa* is a perennial littoral species, very abundant around the Foveaux Strait coastline, and, like the *Pimelea*, commonly present in dune hollows. On a substratum other than sand it forms small loose clumps up to 6 inches in height. In the dune hollows it can keep the tips of its branches above accumulating sand, and, owing to the copious branching of its straggling stems under the sand, it forms a patch of rather open nature with its small, stunted, fleshy leaves lying on the surface of the sand. The individual plants of the Gentian are in some places so numerous that an almost pure turf of this species is formed.

Two other species not infrequently present in the turf of the hollows are *Plantago Raoulii* and *Geranium sessiliflorum* (Fig. 9), the latter being the commoner. Although these occur usually only as isolated individuals, they undoubtedly aid in compacting the surface layers.

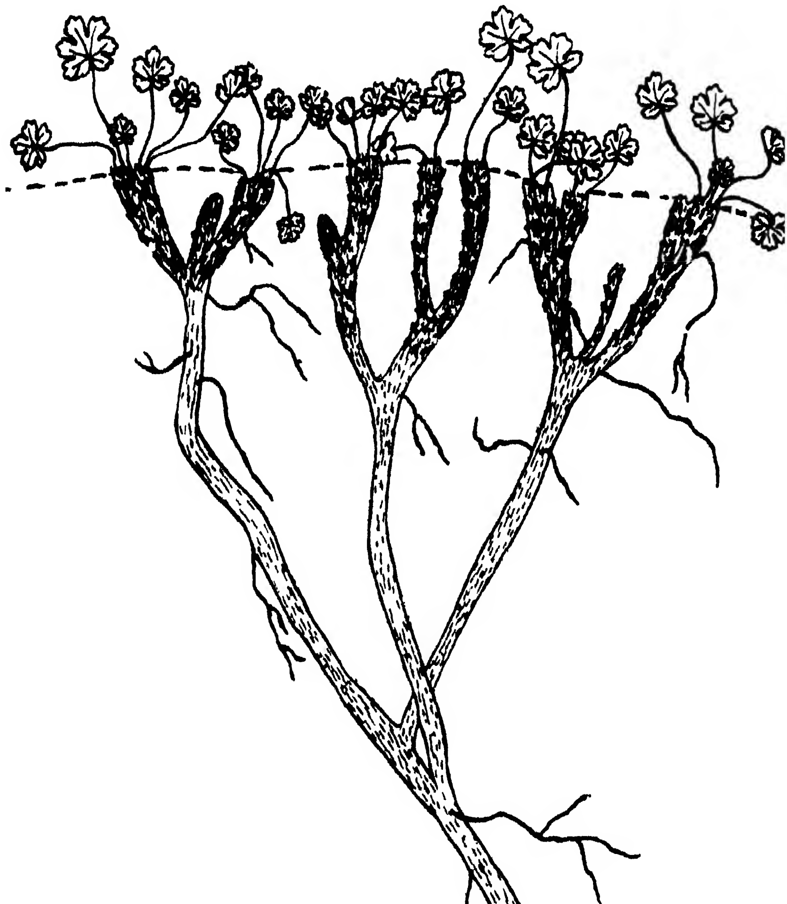

FIG. 9.—*Geranium sessiliflorum* showing stem growth-form in loose sand. Nat. size

(d) The Climax Association.

The dune area, which is here considered, along its eastern boundary is covered by an open shrubbery of *Podocarpus totara* and *P. spicatus*, among which are old large trees of the same two species. The lianes *Rubus schmidelioides, Fuchsia Colensoi*, and *Muehlenbeckia australis* form a conspicuous feature in this shrubbery. This represents an altered Podocarpus forest which is in process of being overwhelmed by the moving sand dunes driven eastward by the prevailing winds. The whole of the district of Otatara, lying between the Invercargill Estuary and the lowermost reaches of the Oreti River (See Map, Fig. 1), is sandy in nature and represents an old and very extensive dune area. The major portion of this area carries

a heavy mixed forest of *Dacrydium cupressinum, Podocarpus ferrugineus, P. spicatus*, and *P. dacrydioides*, with a varied shrubbery in which *Myrtus pedunculatus* and *Suttonia divaricata* are dominant. This will be then the climax association to develop, under the prevailing climatic conditions, on this old sand dune formation. In the seaward direction it passes into the present fringe of moving dunes, as has been stated, through the more open *Podocarpus totara-P. spicatus* type of forest, which has become more or less altered to a Podocarpus shrubbery.

In the case of the largest and most stable dune hollow examined by us (Fig. 6), scattered shrubs of *P. totara* were found to be present over its easternmost upper parts, and this species is clearly spreading down into the hollow. Single young shrubs of the totara have also become established in some of the less mature hollows or on the tussock-covered elevated areas between them. No doubt the next stage in the succession would be that a closer shrubbery of this species would develop and would cover the whole dune area. However, this is present only here and there in the area, since the dune hollows, at longer or shorter intervals of time, are blown out The large hollow shown in Fig 5 is a good example of this, the greater part of the floor having been denuded right down to the firmly compacted substratum The sand has travelled eastward, and is in process of burying the trees on the outskirts of the *Podocarpus* forest. The turf over which the sand is advancing consists mainly of *Acaena microphylla, Fuchsia Colensoi*, and the introduced Canadian thistle. This flat turf represents the floor of the original *Podocarpus* forest covered by a small depth of blown sand and consolidated, and the *Fuchsia* (usually a liane) is thus another example of a species which under these conditions can change its growth-form and become a turf-former. The largest hollow (Fig. 6) has also at some earlier period had its upper end blown out, but has become consolidated again, and carries a uniform plant covering, as previously noted, in which *Poa caespitosa*, intermixed with *Scirpus nodosus*, is dominant throughout.

(e) Summary.

Briefly, then, the sequence in the development of a plant covering on these dunes begins with the establishment of an open association of certain small mat and patch-forming species, aided in places by others which, although not typically patch or mat-formers, under the conditions here prevailing, adopted this growth form. This turf becomes more and more closed owing to the incoming of additional small creeping or rosette species. The tussock grass *Poa caespitosa* next becomes dominant on this turf. Finally a shrubbery of *Podocarpus totara* develops. Judging from what can be observed in places behind the sand dunes where this shrubbery has become dense, the tussock grass tends there to disappear and the composition of the turf to change, the liane *Fuchsia Colensoi*, for example, becoming a member of the turf, and some of the other turf species disappearing. A *Podocarpus totara-P. spicatus* forest here develops. Further back

still, where there is no action of the wind upon the floor, and where the substratum is damper and there is a greater accumulation of humus, a mixed rain forest develops.

NOTES ON THE AUTECOLOGY OF CERTAIN OF THE DUNE SPECIES.

General.

Miss Pegg (4) has published an account of the sand dune plants of New Brighton, Canterbury, devoting her attention to the autecology of the species. Amongst others she considers the following—which also play a part in the Oreti River dune hollows—*Poa caespitosa, Scirpus nodosus, Epilobium nerterioides, Gunnera arenaria,* and *Pimelea arenaria.* The last-named species is represented on the Southland dunes by *P. Lyallii.* She concludes that the species of the moist hollows "for the most part are strong mesophytes," specifically referring to *Epilobium nerterioides* and *E. Billardierianum*, among others, as coming under this category.

In a paper on the mat plants of the Cass River bed, Canterbury, Foweraker (3) deals at length with several species of *Raoulia* (including *R. australis*) and gives figures of the leaf and stem anatomy of certain of them.

Cockayne (1, pp. 23, 31) emphasises the difference between moist and dry dune hollows. He states that the species to be found commonly in the moist hollows "are merely species of other wet or moist stations without the dune area" (p. 23), and, amongst others, mentions *Epilobium nerterioides* and *E. Billardierianum.* Speaking of the *Epilobium* and of certain other "moisture-loving" plants of these damp hollows, he remarks that although the substratum is usually wet and cool, there are periods in the summer when the surface temperature is high and the surface layers are dry, and expresses surprise that such species can tolerate these extreme conditions. In the true dry hollow, on the other hand, there is always a surface layer of sand which is liable to drift. Cockayne refers to the fact that in Southland *Raoulia australis* and *Geranium sessiliflorum* are commonly present in dry hollows (p. 32). Dealing with grassy fixed dunes (p. 30), he states that in Southland certain species of *Acaena* and of *Raoulia* are abundant, and in some cases also *Gentiana saxosa, Poa caespitosa,* and *Pimelea Lyallii* are present along with others.

The Oreti River dune hollows considered in the present paper come properly under the category of dry hollows, although in the mature stage, in which the hollow is extensive and closely covered with turf and tussock, parts of the floor may be more or less moist. In most of these hollows the sand surface, where not covered by vegetation, is loose and liable to be blown, and there is a total absence of halophytic species, which, as Cockayne notes (2, p. 94),

are usually to be found in the true "damp" hollows. On the other hand, the general nature of the plant covering of the Oreti River hollows described above, except for the absence of halophytes, corresponds with that of moist rather than with that of dry dune hollows of other parts of New Zealand. The abundant presence of such species as *Epilobium nerterioides*, *Hydrocotyle americana*, and the species of *Gunnera*, may be especially emphasized with respect to this The reason no doubt is to be found in the prevailingly cool and damp climate of Southland. Evaporation from the sand will be for the most part low, with the result that the surface mantle of loose dry sand will be as a general rule shallower than in the case of dunes in drier parts of New Zealand. This is clearly of importance to the plant life both on account of the fact that the first root of seedlings, and new roots formed from creeping stems, must get down through this mantle before they become anchored and begin to absorb, and also because the loose sand is liable to be blown and so has burying power. Transpiration from the subaerial parts of the dune species also will be, for the most part, low. It is undoubtedly for reasons of this nature, then, that certain "moisture-loving" species are able to take part in the succession on the Oreti River dune-hollows. However, there still remains the fact to be considered that these species will have to endure occasional periods, especially during the summer, of more severe dessication of their subaerial parts.

In dealing with the autecology of the dune-hollow species then, the factors of the environment to be regarded as of especial significance are the loose dry nature of the surface layer and the occasionally strong evaporating power of the air. Our notes will therefore concern both the growth form of the species and also their ability to conserve water. Details should also have been included with respect to the seedling plants, if such had been available. It is obvious that the seedling stage is a very critical one in the establishment of a plant on a surface which is dry and liable to move. These details should concern not only the anatomical characters of the seedling, but also the season of the year at which germination takes place, the depth below the surface at which the germinating seed lies, and the rate of growth of the first root in getting down to the moist substratum. Without having actual observations on these points to bring forward, we surmise that in these Oreti River dune-hollows, under the climatic conditions prevailing, the establishment of the seedlings will not be so precarious, during at least the autumn, winter, and spring months, as in dry dune-hollows in other parts of New Zealand.

There are, as is well known, a number of leaf characters which are usually regarded as efficient in the retardation of transpiration from the leaves, or in the holding in the leaf of a considerable reservoir of water. Among the chief of these are a thick cuticle, sunken stomata, a tomentum, compactness of the inner tissues with

small air spaces, and an unusually large development of these inner leaf tissues with a correspondingly increased ability to hold water. It is, of course, very rarely that these characters are all present together in any one species, and external conditions which are adequately met in one species by a certain combination of leaf protecting characters may be met in another species by other characters. The dune species described below differ from one another considerably in the character of their leaves and other exposed parts.

The following anatomical and growth-form details relate, of course, to the species as they were actually growing in the dune-hollows described in this paper We have selected for description those species which play an especially significant part in the succession.

(a) Raoulia australis var. *alboserecea.*

In the youngest seedlings found it was evident that the first root penetrates down through the upper loose sand layer before the first foliage leaves have fully developed. Both the cotyledons and first foliage leaves are strongly tomentose, and correspond closely in structure with those formed later.

Growth of the above-ground part and development of the small compact cushion is slow, but root development is fast and extends far horizontally just below the loose surface layer. One plant measured had a cushion 2½ inches in diameter, with straggling wiry roots up to 3½ feet long. Neither the stem and branch system nor the roots are as efficient in sand-binding as are those of the true creepers with their more open and more branched mat form

It is known that there are several distinct varieties of *R. australis*. Foweraker (3, p. 14) states that the species, as it occurs on lower river terraces in the Cass River bed, forms a flat, more or less open, quickly growing mat with straggling branches.

On the dunes the small cushions are frequently to be seen more or less buried by the sand. It is well-equipped for withstanding drying. The form and structure of the leaf is closely similar in several of the species of *Raoulia* examined by Foweraker (3). In these species there is a more or less well developed palisade tissue under both surfaces of the leaf (3, Fig. 3). The usual spongy mesophyll is replaced by a water storage tissue of large cells. Both surfaces of the leaf are densely covered with tomentum, the hairs having a characteristic form. The lamina is somewhat folded inward along both sides of the midrib on the adaxial side of the leaf and the leaves more or less closely imbricate over each other. *R. australis* var. *alboserecea* possesses all of these characters (Fig. 10); in addition, the stomata on the outer, abaxial surface of the leaf are noticeably

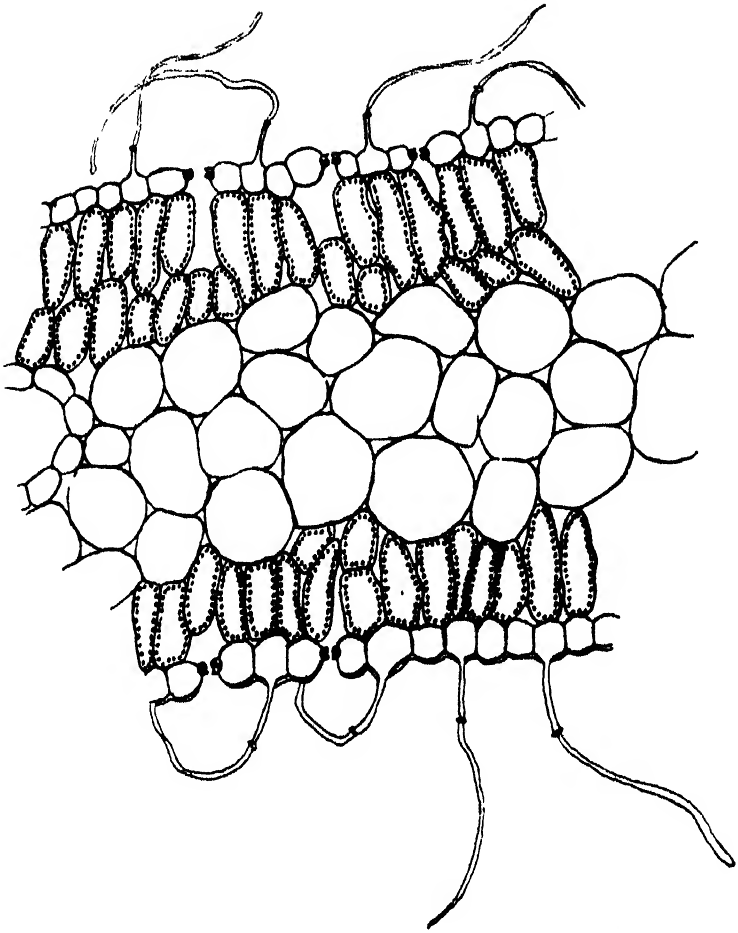

FIG. 10.—*Raoulia australis* var. *albosericea*—Leaf in trans. sect.

sunken below the surface, and the cuticle is heavier on that surface than on the other. The roots are especially wiry and tough, this being due to the heavy groups of fibre which develop in the pericycle.

This species can be regarded then as well fitted, morphologically, to act as the first comer on the bare floor of a hollow. As has been mentioned above, however, it usually seems to play no part in preparing the way for the next comers, so that the succession may be said to begin properly with those species next to be described.

(*b*) *Hydrocotyle americana* var. *heteromeria.*

A creeping, open, mat-forming species, with the rhizome close beneath the surface. Roots are borne freely at each node. The leaf petioles are long, and by their elongation the lamina is kept above the surface of accumulating sand. The rhizomes grow rapidly and branch, and together with the petioles and roots are efficient in binding

the sand. When this species is accompanied by other creeping species, as is commonly the case, the anchoring of the sand is very effective.

The leaf is glabrous, the cuticle not specially thickened, and the stomata (which are present on both surfaces) lie flush with the surface In these respects, then, the leaf could be described as of a mesophytic type. In its internal structure, however, it is not typically mesophytic (Fig. 11). The palisade tissue is three layers

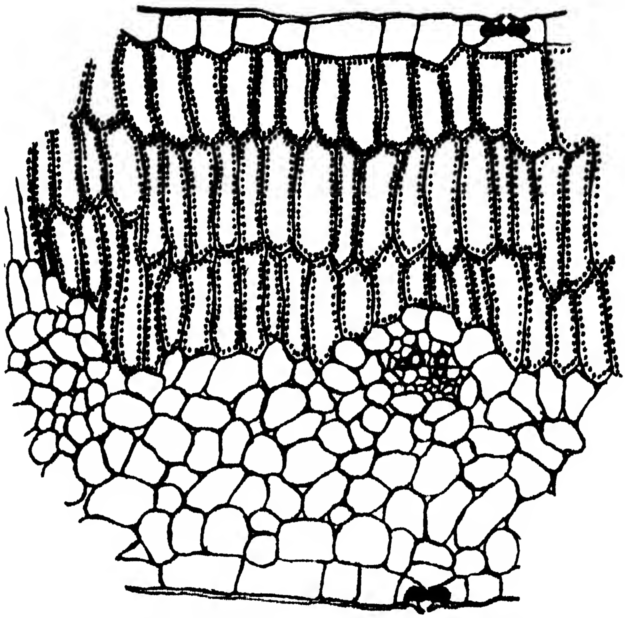

FIG. 11.—*Hydrocotyle americana* var. *heteromeria*—Leaf in trans. sect.

of cells thick, and will hold a considerable amount of water, and the spongy mesophyll is compact with only small air spaces, so that air percolation through the mesophyll will be slow. It would seem that it is to these internal leaf characters that this usually moisture-loving species owes its ability to withstand dessication.

The rhizome has a relatively wide cortex which stores starch so abundantly that a white deposit of it soon collects on the bottom of a watch glass in which sections are placed. No doubt the cortex can also hold a supply of water.

(c) Epilobium nerterioides var. *minimum.*

A freely branching, quickly growing creeper, whose small sessile leaves lie flat on the sand surface. The stems are surface growing and copiously rooted. The rapid elongation of the branches ensures continued life of the plant when the older parts are buried by the drifting sand.

The leaf has the same glabrous nature, unthickened cuticle, and unprotected stomata, as has that of the Hydrocotyle, and also, on the other hand, a correspondingly well developed palisade tissue and compact spongy mesophyll. Raphide sacs and mucilage cells are abundant, especially in the spongy mesophyll, the mucilage cells undoubtedly being effective in holding water We cannot agree with Miss Pegg (4, p. 167) in regarding the leaf of this species as "strongly mesophytic."

(d) Raoulia australis var. *apice-nigra.*

As in the other variety of this species described above, the seedlings show a rapid development of the root system. The mature growth form is an open mat, the creeping stems being usually buried, the short lateral leafy branches growing up erect to the surface, growth being fast enough to keep the leafy parts above the accumulating sand. The leaves are densely tomentose, but less imbricating than in the var. *albosericea.*

The leaf anatomy corresponds very closely with that of the other variety. The stem is strengthened with a continuous zone of cortical fibre, and patches of pericyclic fibre are also well developed. The root has the same remarkable development of pericyclic fibre as in the other variety. Thus both root and stem are well protected from drying and from mechanical injury by moving sand.

(e) Pimelea Lyallii.

This shrubby species usually occurs in inland hill country, and has a low sub-erect habit. On the Oreti River dunes its growth form is similar to that of *P. arenaria,* the flexible straggling stems and main branches being frequently buried to a depth of many feet, especially when growing on the sides of the dune hollows. The leafy parts of the plant rise less above the surface and are more mat-like in *P. Lyallii* than in the other species, but the power of rapid stem elongation under conditions of accumulating sand is noteworthy in both.

The toughness and flexibility of the stems is due largely to the remarkable development of fibre intermixed with the soft bast, the bast forming long wedge-shaped patches separated by the more compressible tissue of the medullary rays. There is also a well-developed periderm. The leaves are covered on their abaxial surface with long silky hairs, these being also present on the younger branchlets and terminal buds. This tomentum undoubtedly plays an important part in retarding transpiration and in protecting the buds from mechanical injury by blowing sand.

The mature leaf of *P. Lyallii* has a thick cuticle on both surfaces. The stomata are of a xerophytic type and are much sunk below the surface (Fig. 12). They are confined to the adaxial surface, although

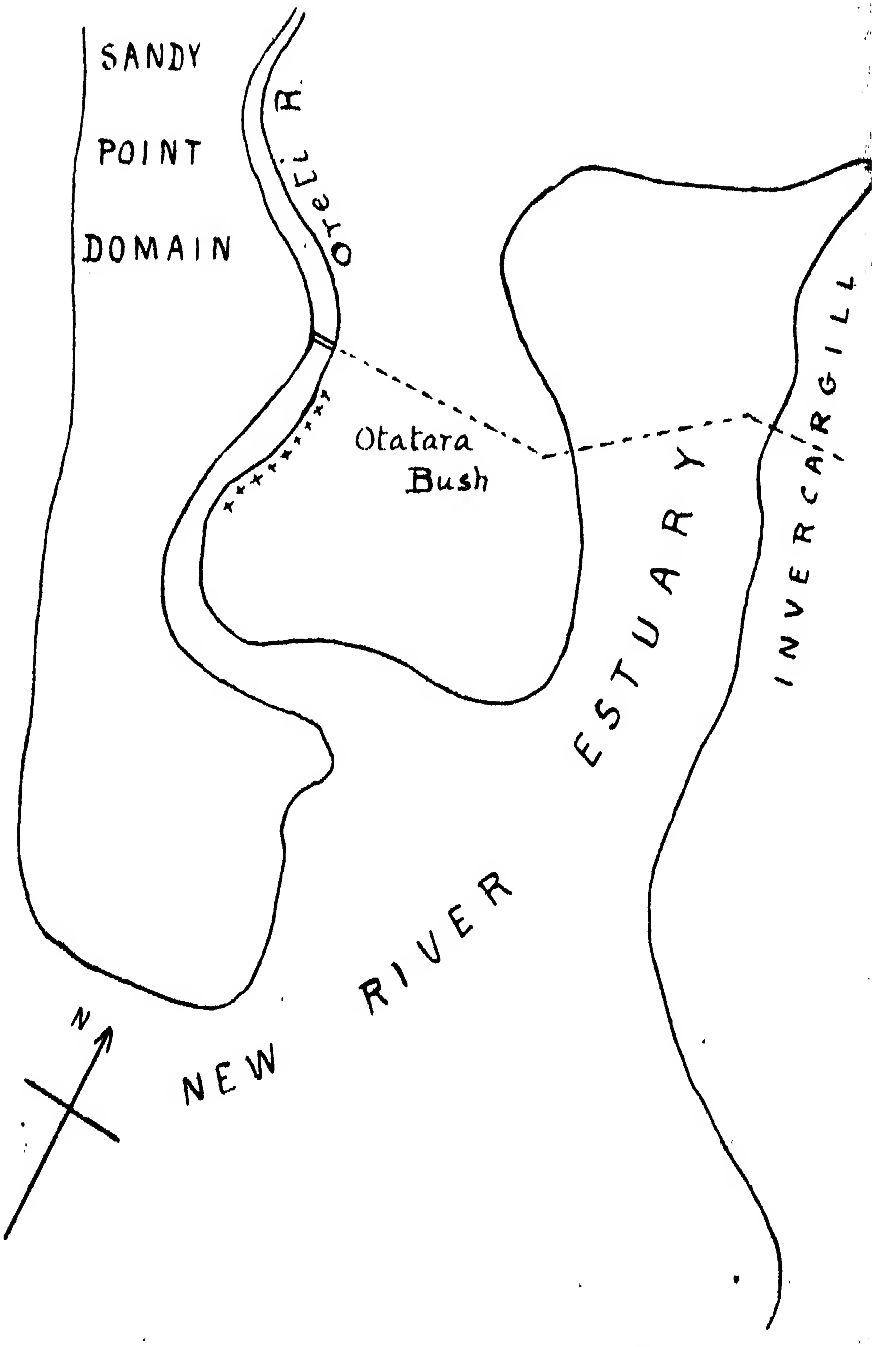

FIG. 1.—Map showing position of the Oreti River dune area described in this paper.

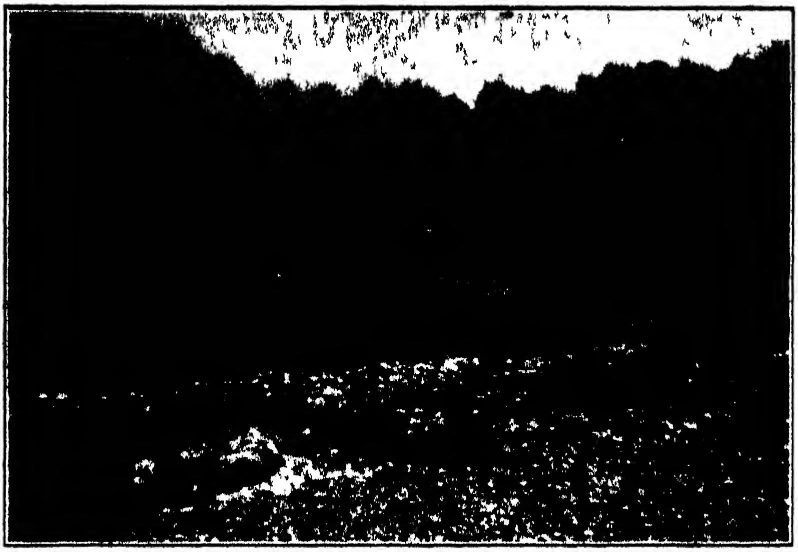

Fig. 2.—Breach in the dune front: the initial stage in the development of a dune hollow.

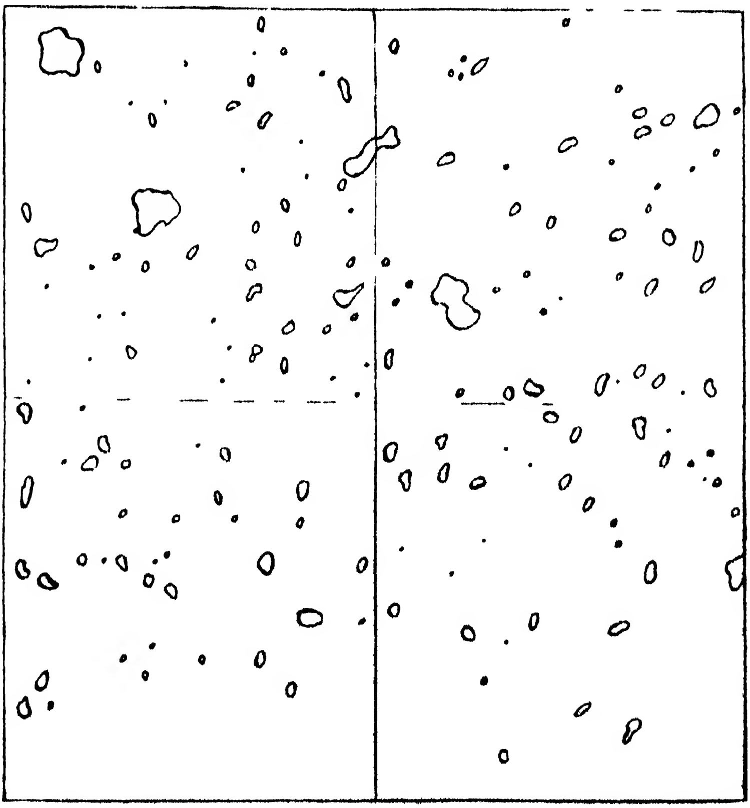

Fig. 3.—Quadrat (10 feet square) at a selected place on the bare consolidated floor of the wind-eroded hollow shown in Fig. 5, showing unusually abundant distribution of cushions of *Raoulia australis* var. *albosericea*. No other plant species present except a few scattered individuals of *Colobanthus Muelleri*.

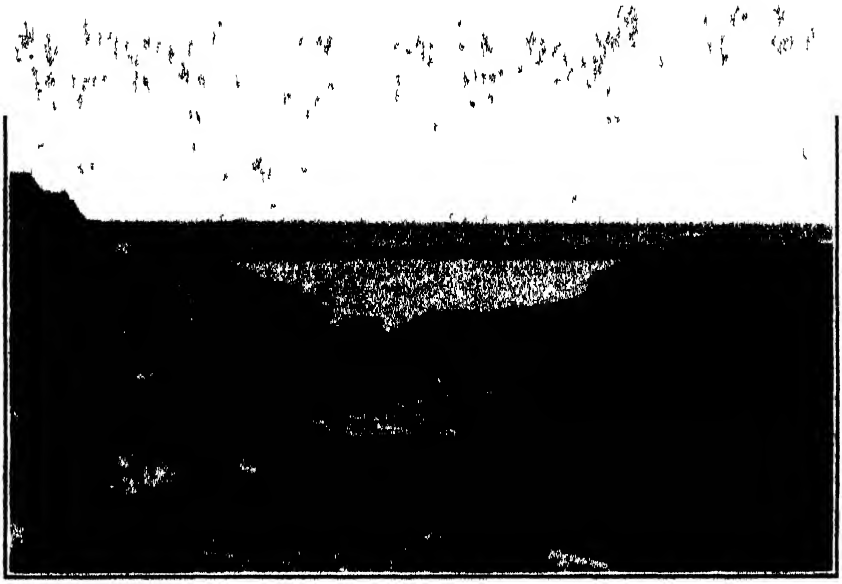

FIG 4 —A dune hollow of medium age and size Two new breaches appear at the lower end

FIG. 5.—A medium aged hollow whose floor and sides have been strongly eroded anew, and whose upper end has been blown out and is overwhelming the *Podocarpus* forest in the background

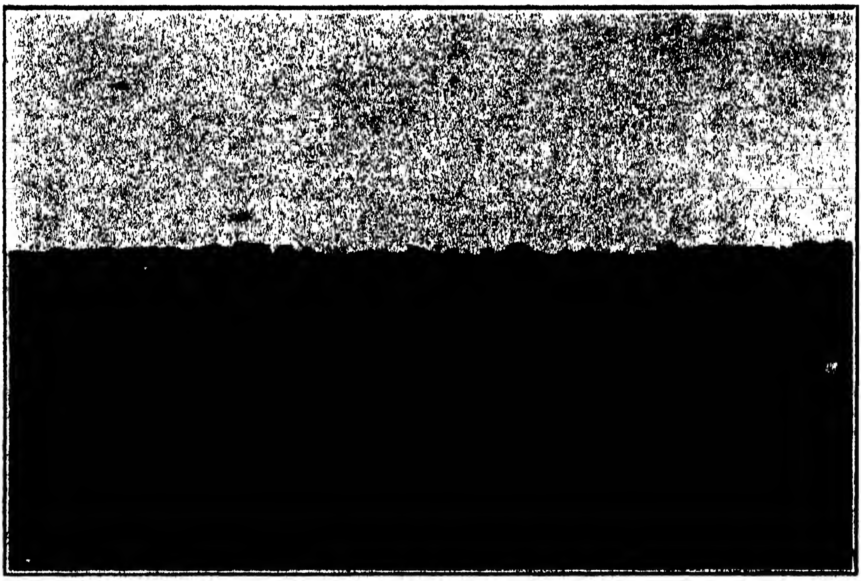

Fig. 6.—A hollow of mature age and size, covered uniformly by *Poa caespitosa* and *Scirpus nodosus*, with a *Podocarpus totara* shrubbery advancing into the hollow at the upper end.

Fig. 7.—A patch of *Gunnera Hamiltoni* advancing over the bare floor of the hollow shown in Fig. 5.

Fig. 8.—*Gunnera Hamiltoni* showing growth-form. Nat. size.

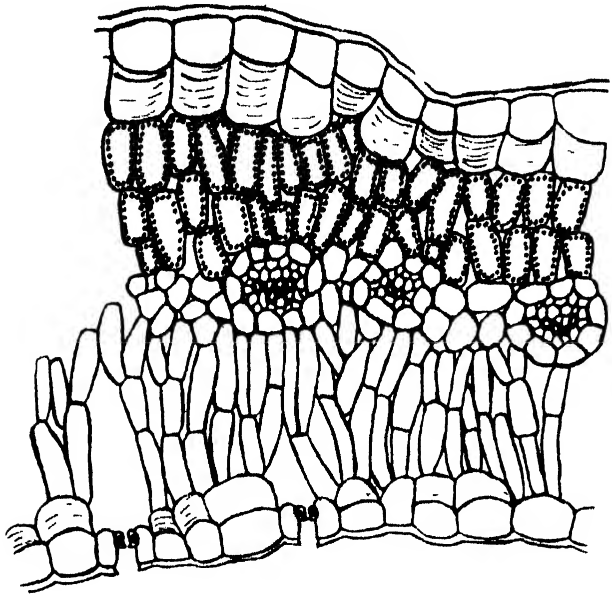

FIG. 12.—*Pimelea Lyallii*—Leaf in trans. sect.

in *P. arenaria* they are present equally on both surfaces. The epidermal cells on both surfaces show the very peculiar gelatinisation of their inner walls which is characteristic of most of the genera in the family (5, p. 716), a feature which accords with the fact that the family as a whole is a dry habitat one. These mucilaginous cell walls will hold water very retentively. Both the spongy mesophyll and the palisade tissue are of a rather loose and open nature with plenty of air spaces, as Miss Pegg found also in *P. arenaria* (4, p. 164). On the whole, however, the leaf must be regarded as efficiently protected from excessive drying.

(f) Geranium sessiliflorum.

This species, like the last named, apparently is common on sand dunes only in Otago and Southland (2, p. 91). In its typical form there is a multicipital crown to the tap root lying at or just above the soil surface. In its dune form this develops as an elongated, much branched stem, bearing adventitious roots, and buried right up to the branch apices (Fig. 9). The plant is clearly able to keep pace with the accumulation of sand around it, and keeps its leaves above the surface. The stem and branches are stout and woody, and densely clothed in their upper parts with the bases of the old petioles and their large scaly stipules. In their lower parts they are worn clean of the leaf bases by the moving sand, but are further protected by a thick periderm. The deep growing woody tap root also has a well-developed periderm. In the dune form the leaves are only about one-third the diameter of those of the type.

This species on the dunes thus forms small patches, the branches of the stem effectively anchoring the sand around the plant. As it sometimes occurs in considerable numbers on the floor of hollows, it can be regarded as playing an important part there.

The leaf lamina and petiole carries a certain amount of silky tomentum, and, more important still, the branch apices are closely covered by the scaly stipules of the leaves, and are thus well protected from dessication and mechanical injury.

The leaf anatomy is closely similar to that of the *Hydrocotyle* and *Epilobium* described above.

(g) Gunnera Hamiltoni.

This species forms very dense, extensive patches. It has a stout creeping rhizome at the surface of the sand which branches copiously, bearing a clump of stout rigid leaves at each node (Fig. 8). The nodes are near enough together for the leaves to form a closely interlocking system, with the result that in the main patches the surface of the sand is nowhere visible and is completely protected from the wind. These patches are so dense that it is but rarely that any other species is to be seen growing in them. From the edge of the patch the rhizomes extend outwards very rapidly (Fig. 7).

The rhizome is up to 5 or 6 mms. thick. Starch is abundantly present in the very wide cortex and also in the pith, and no doubt these tissues will hold much water also. The roots are copiously provided with root hairs to such an extent that, when dug out, a cylinder of the moist sand firmly ensheaths each.

The leaf petiole is long so that the lamina is rarely buried by the sand. The lamina is thick and firm. The distinction between palisade and spongy mesophyll is not clearly marked, the cells of the former being scarcely at all elongated at right angles to the surface. There are, however, 3 or 4 layers under the abaxial epidermis, very compactly arranged, which represent the palisade. There is a considerable spongy mesophyll which gives the main thickness to the leaf. This also is compact, with but small air spaces. The stomata are on both surfaces and are not sunken. The cuticle on both surfaces is comparatively thin. Miss Pegg has described with a figure the leaf anatomy of *G. arenaria* (4, p. 168), this corresponding fairly closely with that of *G. Hamiltoni*. She speaks of the leaf as "strongly mesophytic." This we cannot agree with, since the extensive and compact inner tissues will hold ample water, and air movements through them will be considerably retarded.

(h) Gentiana saxosa.

This is a herb of comparatively small size which can play the part of a true turf former. In some of the Oreti River dune hollows it occurs in large numbers, even on the sloping sides of hollows where the sand is loose and bare. Commonly all that is to be seen of the plant are the small oval leaves, ½ to 1 cm. long, lying flat on the surface. The numerous branches, buried in the sand, will tend to stabilise the surface layer.

The leaf is fleshy, and the cuticle, though not thick, is better developed than in most of the other dune species already described. The stomata lie flush with the surface. The palisade tissue is compact and from 4–5 cells deep. The spongy mesophyll is also specially thick, but is open in character with plenty of large air spaces. The leaf can clearly hold much water in its tissues, and this, together with the rather well developed cuticle, forms a combination of characters which probably adequately explains why the leaves never show, even on a hot, dry, autumn day, so far as we have observed, any signs of wilting.

SUMMARY.

An account is given in this paper of plant succession as it takes place on sand dunes under the climatic conditions obtaining in the extreme south of New Zealand.

Some of the most characteristic of New Zealand dune species are absent from the area described, e.g., *Scirpus frondosus*, *Coprosma acerosa*, and *Calystegia soldanella*, as also is the introduced marram grass. Moreover, *Pimelea Lyallii* takes the place of *P. arenaria* of other New Zealand dune localities. *Gunnera Hamiltoni* is altogether confined to this southern coast. *Gentiana saxosa*, abundant on the Southland coast, is only found elsewhere in New Zealand on the western coast of the South Island. Thus the plant covering of the Oreti River dunes shows strong floristic differences from that of most other New Zealand dune areas.

The dune hollows described above are of the dry (1, p. 32) rather than the moist type, but the turf which develops in them is somewhat similar to that of a typical moist dune hollow. This turf consists very largely of species which are not true dune species at all, but which are widely distributed outside dune areas. Some of these can be described as " moisture-loving " plants, and it is largely due to their presence that the turf of these dune hollows has a more or less similar facies to that of a true moist hollow. That these hollows come under the category of true dry hollows follows from two facts, firstly that the surface sand layer on the floor is dry and liable to be blown, and, secondly, that in none of them are halophytes present as they so commonly are on moist stable sand flats. In this latter respect the plant covering of the damp sandy flats which lie behind the dunes on the western side of the Oreti River is in strong contrast to that of the sandy hollows of the eastern side described in this paper, the turf covering of the former containing abundantly such halophytes as *Selliera radicans*, *Samolus repens*, *Triglochin striata* var. *filifolium*, and *Lilaeopsis novae-zelandiae*.

The species which play an important part in the earlier stages of the succession on the Oreti River dunes are mat or patch-forming plants which are able to bind the sand in their immediate neighbourhood, and which can by rapid growth keep their leaf system above the accumulating sand. It has been shown above that the subaerial parts of these species must be regarded as protected, to a greater or

less extent, from excessive drying. Some of them are typical mat-formers with creeping stems. In the case of certain others, however, viz., *Gentiana saxosa*, *Pimelea Lyallii*, and *Fuchsia Colensoi*, the last named of which occurs only in the shrubbery which is being overwhelmed by the moving dunes, and to a certain degree *Geranium sessiliflorum*, the patch growth form is not the usual one for the species, and must be regarded as an epharmonic form, a direct adaptation to sand dune conditions.

A fruitful line of study, if we had been able to undertake it, would be to compare dune-growing individuals with individuals growing under " mesophytic " conditions in the near neighbourhood, or with individuals which had been transplanted from the dunes into the garden, with respect to details in the growth form or in the stem and leaf anatomy. Such a comparison would help to a better understanding of the ecology of the species, by indicating which characters are under the direct control of the environment, and to what extent An extensive study of this nature has been carried out by Miss Anna Starr for the dune-growing species of Indiana, U.S.A. (6), and she finds that species normally belonging to mesophytic localities, usually show when growing on dunes well marked modification in both leaf and stem anatomical characters in accordance with the new environment.

Another line of investigation, referred briefly to earlier in this paper, should concern the establishment of the seedlings of the true pioneer species. The significance of the behaviour of the seedling on bare sand surfaces becomes apparent when it is remembered that the seeds of not a few of the plant species growing in the immediate neighbourhood will be, without doubt, scattered freely on bare surfaces, but that it is only with respect to certain definite species that the seedlings are able to establish themselves.

Postscript.

Since the above account was written, the senior author has continued the study of the consolidation of dune flats in other coastal localities in Southland and Otago where the climatic conditions are similar to those of the Oreti River area.

West of Colac Bay, on the Foveaux Strait coast, there is an extensive dune area which is undergoing continuous wind erosion. Certain of the flats are dry and are swept more or less down to the shingly substratum. Here the first species to occupy the ground is *Raoulia australis* var. *albosericea*, followed by the same species of *Epilobium*, *Hydrocotyle*, and *Colobanthus* as play the role of pioneers in the dry dune hollows in the Oreti River area. The *Raoulia* forms large flat cushions up to several feet in diameter, and undoubtedly plays an important part, along with the others, in arresting sand movement. The seedlings of this species, in all stages of development, were found to be abundant in the driest season of the year (January). The more extensive flats further back from the shore dunes are distinctly of the moist type. Here there is a firm sandy floor on which the halophytes *Lilaeopsis novaezelandiae* and *Triglochin striata* var.

filifolium, together with the moisture-loving *Hydrocotyle trifoliata*, are the pioneers. These form a rapidly extending turf formation, which on older flats of the same type has become remarkably dense owing to the incoming of such non-halophytic, moisture-loving species as *Pratia angulata*, *Mazus radicans*, *Nertera Balfouriana*, *Marchantia*, etc. Where this dense native turf is better drained on slight elevations a few inches above the surrounding surface, clovers and certain other introduced species begin to play a part, thus indicating a further stage in the succession.

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Tertiary Foraminifera from Chalky Island, S.W. New Zealand

By Walter J. Parr, F.R.M.S.

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Introduction.

The foraminifera here described were collected on Chalky Island, one of the islands in the fiord region of New Zealand, by the expedition organised by Professor W. N. Benson, of the University of Otago, to study the geology of Chalky and Preservation Inlets. For the opportunity of investigating them I am indebted to Professor Benson and to Professor J. A. Bartrum, of Auckland University College, to both of whom I offer my sincere thanks. I also desire to express my appreciation of the assistance my friend, Mr Frederick Chapman, the Australian Commonwealth Palaeontologist, has given in the identification of several species and in taking the photographs illustrating this paper.

The rock in which the foraminifera occur is a hard grey-white marl, with included patches of grit which, in one sample of material, is present as a thin layer of calcareous sandstone. Owing to its compact nature, the foraminifera have necessarily been examined in thin sections of the material. Specific determination is, therefore, not possible in the majority of cases, but a very interesting series has, nevertheless, been obtained. Specimens are fairly common, and it is noteworthy that the larger species occur in the grittier portions of the rock, apparently as the result of the concentration of the larger particles of sediment by current action. The genera best represented are *Cibicides* and *Amphistegina*. The most striking discovery, however, is a new species of *Halkyardia*, a genus of which there appear to be only two previous records, both from the Middle Eocene of Europe. There are also several examples of the typically Upper Cretaceous genus *Gümbelina*. Associated with the foraminifera are small polyzoans, echinoid spines, ostracoda, and siliceous sponge spicules of the genera *Spirastrella ?*, *Geodites*, *Corallistes*, *Pachastrella*, and a Dictyonine hexactinellid. These sponges have all been recorded previously by Hinde and Holmes (1892, pp. 178-262) from the Tertiary of the Oamaru district and are also known from present-day seas.

A preliminary list of the foraminifera has been included by Professor Benson in his report on the stratigraphy of the area, which has already been published (Benson, 1933, p. 426). One or two alterations to this have been made in the list given below.

The foraminifera are generally characteristic of warm water of moderate depth. Judged by them, the age of the deposit is probably Middle Tertiary. The assemblage most closely resembles some of those recorded by Mr Chapman and by myself from the

Waitemata beds in the vicinity of Auckland, in which we have a similar association of such species as *Amphistegina* sp. aff. *lessonii*, *Vulvulina* sp. aff. *pennatula* (this is known only from the Miocene of the North Island), *Spiroplectammina parallela*, *Ammodiscus* sp. aff. *incertus*, and *Rotalia* sp. aff. *calcar*. The important genus *Amphistegina* is, as has been pointed out previously by Chapman and others, particularly typical of Miocene deposits. In South-Eastern Australia it is confined to the Miocene, and, according to Chapman (1926, p. 90), is, in New Zealand, best represented in the Miocene. An older element in the Chalky Island fauna is supplied by *Gümbelina* which, although generally found in the Upper Cretaceous, is known definitely to occur in the Eocene and has been recorded by Schubert (as *Pseudotextularia*) from the Miocene of the Bismarck Archipelago. *Halkyardia* has not been considered in this discussion, as so little is known of its distribution. It is probable, however, that this will be found to be similar to that of the closely-related *Linderina*, which, in Europe, is, like *Halkyardia*, an Eocene form, but, in the East Indies, occurs in the Miocene.

LIST OF SPECIES.

1. ? *Marsipella elongata* Norman	rare
2. *Ammodiscus* sp. aff. *incertus* (d'Orbigny)	rare
3. *Spiroplectammina parallela* Cushman	1
4. *Textularia* sp.	1
5. *Vulvulina* sp. aff. *pennatula* (Batsch)	1
6. *Verneuilina* sp. aff. *bradyi* Cushman	1
7. *Nodosaria parexilis* Cushman and K. C. Stewart	1
8. *Nodosaria antipodum* Stache	rare
9. *Melonis pompilioides* (Fichtel and Moll)	1
10. *Elphidium* sp. aff. *macellum* (Fichtel and Moll)	rare
11. *Gümbelina* sp. cf. *globulosa* (Ehrenberg)	rare
12. *Bulimina* sp. cf. *pyrula* d'Orbigny	
13. *B.* sp.	
14. *Bolivina* sp. A.	rare
15. *B.* sp. B.	
16. *Uvigerina* sp. aff. *interrupta* Brady	
17. *Pullenia sphaeroides* (d'Orb.)	
18. *Rotalia* sp. aff. *calcar* (d'Orbigny)	
19. *Amphistegina* sp. aff. *lessonii* d'Orb.	common
20. *Globigerina* sp. A.	common
21. *G.* sp. B.	frequent
22. *Cibicides refulgens* Montfort	common
23. *C.* sp.	rare
24. *Planorbulina* sp.	rare
25. *Halkyardia bartrumi*, sp. nov.	common
26. *Gypsina* sp. cf. *howchini* Chapman	1
27. *Carpenteria proteiformis* Goës	1

NOTES ON THE MORE IMPORTANT SPECIES.

? *Marsipella elongata* Norman.

In the rock sections there are several examples of a tubular, agglutinated foraminifer, the wall of which consists almost wholly of short fragments of siliceous sponge spicules fitted together to form a more or less diagonal meshwork. The only species showing a similar wall structure appears to be *Marsipella elongata* Norman, in which,

however, the spicules are less regularly arranged and there is a large percentage of sand grains also used, although it is variable in this respect.

Ammodiscus sp. aff. *incertus* (d'Orbigny).

This form is represented by one free megalospheric specimen and two sections. The same species is common in the Awamoan (Lower Miocene) of the Gisborne district, in the North Island. It differs from typical *A. incertus* in having the last whorl in the adult slightly uncoiled.

Spiroplectammina parallela Cushman.

Spiroplecta annectens Brady (*non Textularia annectens* Parker and Jones), 1884, p. 376, pl. xlv, figs. 22, 23*a*, *b*. Schubert, 1911, p. 52. Chapman, 1926, p. 31, pl. viii, fig. 1.

Spiroplectammina parallela Cushman, 1931, p. 26, pl. iv, figs. 1*a*, *b*.

A fine example, cut in the median plane, occurs in a rock section sent by Professor Bartrum. This species has recently been shown to be distinct from the Liassic form described by Parker and Jones as *Textularia annectens*, which has a different development and is now placed in the genus *Spiroplectinata*.

The type specimens of *S. parallela* were from the Late Tertiary of Fiji. The species was dredged by the "Challenger" Expedition as a living form off Raine Island, Torres Strait, at a depth of 155 fathoms. Chapman's record quoted above is from the Upper Eocene of New Zealand, and that of Schubert from the Miocene of New Mecklenburg, in the Bismarck Archipelago. I have previously had the species from the Waitemata beds in the vicinity of Auckland.

Vulvulina sp. aff. *pennatula* (Batsch).

(Plate 20, fig. 1.)

There is an excellent median section of a megalospheric example of a species of *Vulvulina* in another of Professor Bartrum's slides. The test begins with a short planospiral series of chambers and the wall is distinctly tubulated. The species is probably the same as one which occurs in the Waitemata beds at Motuihi Island and Granger's Creek, Whitford, near Auckland, and which appears to be closely related to *V. pennatula*.

Nodosaria parexilis Cushman and K. C. Stewart.

Nodosaria exilis Schwager (*non* Neugeboren), 1866, p. 223, pl. v, fig. 52.

N. parexilis Cushman and K. C. Stewart, 1930, p. 55, pl. ii, figs. 13-15.

There is one section of a typical example. This species is common in the Waitemata beds exposed on Manukau Harbour, near Auckland. It was described from the Pliocene of California; Schwager's specimens were from the Pliocene of Kar Nicobar, in the Andaman Islands.

Nodosaria antipodum Stache.

Nodosaria antipodum Stache, 1864, p. 204, pl. xxii, figs. 19*a-e*.

N. radicula (Linné), slender var.: Chapman, 1926, p. 52, pl. iii, figs. 19*a-e* (after Stache).

There is one good example of this species exposed on tured surface of the rock. It also occurs in the sections. *N. an* appears to be one of the group containing *Dentalina soluta* Reu. *D. pomuligera* Stache. It is characterised by its practically str test, many sub-globular chambers of almost even diameter, thick s wall and limbate sutures. Stache did not figure a complet The Chalky Island examples are likewise fragmer consisting of nine chambers and measuring 3.2

The type specimens of *N. antipodum* we of Whaingaroa Harbour. Mr C. R. Laws, M. warded some fine examples of this species from th near Gore, Otago, which have been assigned by Dr Oligocene.

Gümbelina sp. cf. *globulosa* (Ehrenberg)

There are several sections of a species of *Gümbelina* near *globulosa* (Ehrenberg). The specimens are exactly similar to thos occurring in the so-called hydraulic limestones of North Auckland, which are considered to be of Upper Cretaceous or Early Tertiary age.

Although *Gümbelina* is typically an Upper Cretaceous genus, its range extends into the Tertiary. Schubert (1911, p. 25) has recorded what is probably the same as the present form under the name of *Pseudotextularia* cf. *globulosa* (Ehr.), from the Upper Miocene *Globigerina*-marl of Katendan, New Mecklenburg, in the Bismarck Archipelago.

Uvigerina sp. cf. *interrupta* Brady

There is an example of what is almost certainly the above species in one of the rock sections. *U. interrupta* is an Indo-Pacific form which occurs in moderately deep water off Papua, in the Red Sea, and elsewhere. It is frequently met with in the Miocene of Victoria.

Amphistegina sp. aff. *lessonii* d'Orbigny.

(Plate 20, fig. 2.)

Examples of a species of *Amphistegina*, near *A. lessonii*, are common in the gritty parts of the samples. The sections show it to be strongly beaded around the aperture. Chapman's records of the genus from New Zealand were from the Oligocene and the Miocene; it is abundant in the Miocene of Victoria.

Cibicides refulgens Montfort

Typical examples of this species are common in the rock sections and there is also one free specimen. This is a widely distributed form in the living condition. The only records as a fossil from New Zealand are from the Miocene.

Planorbulina sp.

There are several sections of a species near *P. mediterranensis* d'Orb. This genus has not previously been recorded from New Zealand

Halkyardia bartrumi, sp. nov.

(Plate 20, figs. 3-6; text-figs. 1-3.)

Test free, biconvex to sub-conical, beginning with an embryonic s of two or more rounded to crescentic chambers, later chambers ' s, in end view rounded to sub-hexagonal or occasion- ılar, elongate, frequently with the lateral walls d, extending into the umbilical region which 'y tubulated shell material; superior surface of coarsely perforated shell material; no general ıication with the exterior being through the coarse the shell wall.

.er up to 1.15 mm.; height up to 0.6 mm.

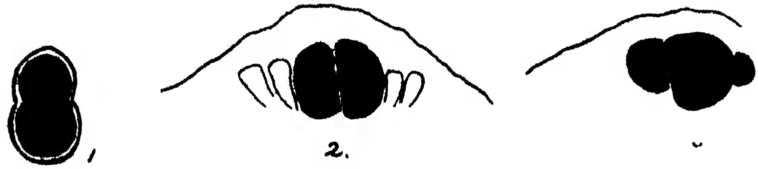
.otype and other figured specimens in collection of Dominion .um, Wellington, New Zealand.

It is of great interest to meet with the genus *Halkyardia* in the Tertiary of New Zealand, as previous records, with the exception of one which is referred to below, are from the Middle Eocene of Southern Europe. The genotype is *H. minima* (Liebus), which was described (Liebus, 1911, p. 952, pl. ii, figs. 7*a-c*) from the Middle Eocene of Smokovic, in North Dalmatia, under the name of *Cymbalopora radiata* Hagenow, var. *minima*, and subsequently recorded by Heron-Allen and Earland in the work of Halkyard (1919, p. 110, pl. vi, figs. 8, 9) on the foraminifera of Biarritz, when they also described the genus. A second species, *H. ovata*, was described in Halkyard's paper, this being apparently the only other species described.

Very recently Galloway (1933, p. 317) has recorded the genus from the Oligocene of Mexico, but notes "There is some doubt about *Halkyardia* being a foraminifer. Some specimens of the genus from the Oligocene of Mexico, which have all the characters of the genus, bear considerable resemblance to knobs on echinoid plates." It is difficult to understand why such a doubt should have arisen in view of the figures and descriptions given of the genus in Halkyard's paper, especially when it is considered that these have the authority of such workers as Heron-Allen, Earland, and Halkyard. Their observations on the genotype are confirmed by those of the writer on the present species.

H. bartrumi was at first considered to be merely a variety of *H. minima*, which, in many respects, it closely resembles, but, with more material available, it is clear that the two are specifically distinct. *H. bartrumi* is twice the size of the European form, which measures only 0.5–0.6 mm. in diameter. More important differences are the nature of the embryonic apparatus and the corrugation of the dividing walls between the chambers in the present species.

In the only section of *H. minima* which has been figured (yard, 1919, pl. vi, fig. 9), the test begins with a single chamber, which is immediately followed by the annular chambers. The embryonic apparatus in the New Zealand on the contrary, consists of two or more chambers. Genera are two, when the arrangement is similar to that seen in t *Lepidocyclina (sensu stricto)* (Plate 20, fig. 3; text-figs.



this number may be exceeded (Text-fig. 3). All of the speci of which a radial section has been obtained are megalospheric. Th embryonic chambers of *H. bartrumi* may be compared with those of *Linderina buranensis,* described by Nuttall and Brighton (1931, p. 58, pl. iv, figs. 8-14; text-fig. 3) from the Middle Eocene of Somaliland.

The chamber walls are single. The corrugation of the lateral walls is usually found in the later rings of chambers and is somewhat irregular. When seen in vertical sections, it gives a pseudo-septate appearance to the chambers, such as is shown in Fig. 4 on the plate. This was very misleading until additional material, received from Professor Benson, enabled good horizontal sections to be obtained which explained this structure (Plate 20, fig. 6).

There are two classes of perforations in the test. The embryonic chambers are very finely perforated, as also are parts of the walls between the chambers in the annular series. The outer end of each annular chamber and the chamber floors have numerous coarse perforations.

From the study of the considerable number of sections of *H. bartrumi* available, it appears to the writer that the genus is very closely related to *Linderina,* from which it differs in having the median layer of chambers strongly concavo-convex, with a corresponding modification in the shape of the chambers. The present species, in the character of the embryonic apparatus and the very regularly arranged rings of chambers, as well as the lateral layers of shelly material, shows some affinity with the orbitoidal genera such as *Monolepidorbis* Astre and *Orbitoides* d'Orbigny.

The name of this species is given in honour of Professor J. A Bartrum, to whom I am indebted for the first samples of material containing this interesting form as well as for much other material from the Tertiary of New Zealand.

Gypsina sp. cf. *howchini* Chapman.

There is a vertical section of a small specimen which agrees with similar sections of Victorian examples of *G. howchini* in having the chambers of the median plane larger than the lateral chambers and also in the shape of the test. The only other form resembling it is

icularis (Parker and Jones), var. *discus* Goës, which is unknown
il and has been recorded from Recent tropical seas only.
tini was described from the Lower Miocene of Batesford,
(Chapman, 1910, p. 291, pl. lii, figs. 4*a*, *b*; pl. liii, figs. 3-5),
been recorded only from the Miocene of Victoria.

Carpenteria proteiformis Goës.

species is represented by one typical example. It has been
by Chapman from the Oligocene, and by the writer from
ocene, of New Zealand.

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Explanation of Plates.

Fig. 1.—*Vulvulina* sp. aff. *pennatula* (Batsch). Median vertical section showing coiled early stage. × 55.

Fig. 2.—*Amphistegina* sp. aff. *lessonii* d'Orbigny. Vertical section. × 37.

Figs. 3-6.—*Halkyardia bartrumi*, sp. nov. Fig. 3—Holotype (a young individual). Median vertical section showing complex embryonic apparatus. × 55. Fig. 4—Vertical section through an adult specimen just outside centre of test. The apparent subdivision of the tubular chambers is due to the corrugation of the dividing walls. × 37. Fig. 5—Tangential section cut midway between the centre of the test and its periphery. × 55. Fig. 6—Horizontal section near the base of test. This shows the corrugated dividing walls. × 55.

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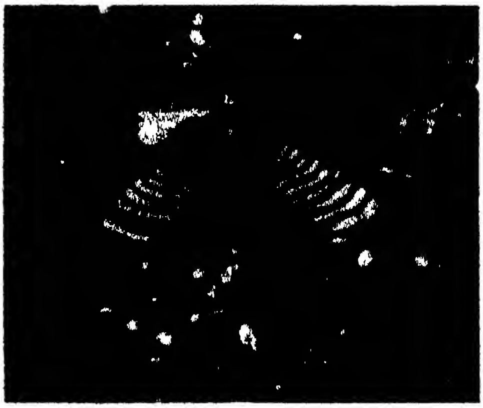

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Fig 1.—*Vulvulina* sp. aff. *pennatula* (Batsch). Median vertical section showing coiled early stage. × 55. Fig. 2.—*Amphistegina* sp. aff *lessonii* d'Orbigny Vertical section. × 37 Figs. 3-6.—*Halkyardia bartrumi*, sp. nov Fig. 3.—Holotype (a young individual) Median vertical section showing complex embryonic apparatus. × 55. Fig. 4.—Vertical section through an adult specimen just outside centre of test. The apparent subdivision of the tubular chambers is due to the corrugation of the dividing walls × 37. Fig. 5.—Tangential [illegible]n cut midway between the centre of the test and its periphery × 55 [illegible] 6.—Horizontal section near the base of test This shows the corrugated [illegible]g walls. × 55.

Note on the Occurrence of Clinohypersthene and Enstatite-Augite in the "Norite" from Bluff, New Zealand

By HAROLD SERVICE, Lubecki Research Scholar, Otago University.

[*Read before the Otago Institute, September 12, 1933; received by the Editor, September 30, 1933, issued separately, September, 1934.*]

RECENT investigations upon the "norite" of Bluff Hill, Southland, have shown that in this rock most of the pyroxene hitherto recorded as hypersthene and augite (e.g., Wild, 1911) is actually either clinohypersthene or enstatite-augite. Since, as far as the writer is aware, the latter two have not been recognised as such in New Zealand rocks, their optical properties are here noted

(1) Clinohyperst[illegible] The following properties were obtained: Fine lamellar twinnin[illegible] (100) frequently developed. Mean refractive index = 1·72. Birefringence = 0·023. Optic plane parallel to the traces upon (001) of the (100) twins, i.e., perpendicular to the clinopinacoid. X parallel to the b axis. Maximum extinction angle (Z to c) = 35°. Negative. 2V = 30° ± 3°. Pleochroism marked, with X = Y = pale rose pink, Z = pale apple green, and absorption Z > X = Y. The optic axial angle was measured by Becke's graphical method, and the refractive index by oil immersion.

These properties agree closely with those given for the rare species clinohypersthene by Winchell (1929, pp. 43, 157), who has here evidently modified his former statement that the mineral has positive optical character (1927, p 181). Gotthard (1928) notes that the clinohypersthene of N.E. Bohemia is very similar to normal hypersthene, but has extinction angles (Z to c) up to 10°. Again, Tsuboi (1920, p. 83) records both hypersthene and clinohypersthene in basaltic rocks from Japan, and mentions that in these minerals the optic planes are parallel to and transverse to the c axis respectively; they are otherwise alike except for the inclined extinction of the monoclinic mineral. Presumably, then, the sign is negative in both of the above cases.

The negative sign, low optic axial angle, orientation of the optic plane at right angles to (010), frequent lamellar twinning, and pleochroism conclusively distinguish the mineral from other monoclinic pyroxenes.

(2) Enstatite-augite. Less common than the clinohypersthene is a pyroxene with inclined extinction, positive optical character, low optic axial angle, and pleochroism in shades of faint pinkish-green. Fine lamellar twinning parallel to (100) is universal, and schiller inclusions are seen in end section to be arranged in lines parallel to the traces of these twins. The optic axial angle is small (2V = 25°, assuming β = 1·7), and the plane of the optic axes

is the clinopinacoid—i.e., is transverse to the (100) twinning-plane. The extinction angle could not be determined accurately, but is not large.

Fermor (1925b) has summarised the literature dealing with the enstatite-augite series of monoclinic pyroxenes. They all have low optic axial angle and positive sign. The optic plane in clino-enstatite is perpendicular to (010), but as the diopside-hedenbergite content increases the optic axial angle decreases about Z in this plane until the mineral becomes uniaxial.* It then increases about Z in the (010) plane until the value of 59° is reached for pure diopside.

The mineral from Bluff may thus be identified as an enstatite-augite relatively rich in diopside-hedenbergite; the pleochroism suggests the presence of appreciable iron. Colour and pleochroism appear to vary in the enstatite-augite series (cf. Winchell, 1927, p. 182), though pale brownish tints with very faint pleochroism are characteristic (e.g., Thomas and Bailey, 1924, p. 284; Fermor, 1925a, p. 116). Pale pink distinctly pleochroic varieties have been recorded, however, by several writers (e.g., Tyrrell, 1909, p. 306; Dixey, 1922, p. 325)

This occurrence of pyroxenes of the pigeonite series as important constituents of the typically plutonic Bluff "norite" is of interest, as it bears upon the views advanced by Barth (1931) and Tsuboi (1932) as to the course of crystallisation of pyroxene from basic magmas. According to Barth, the first pyroxenes to crystallise normally are rich in diopside, but as crystallisation proceeds the pyroxene becomes gradually enriched in $(Mg,Fe)SiO_3$, and ultimately attains the composition of pigeonite.

Tsuboi, however, has criticised this view, and has reached the following general conclusions:—

1. In the intratelluric stage of crystallisation (designated as "condition A") either monoclinic or orthorhombic pyroxene commences to crystallise, according to whether the initial liquid lies in the field of monoclinic or orthorhombic pyroxene in the ternary system $CaSiO_3$ — $MgSiO_3$ — $FeSiO_3$. The liquid then changes in composition until the boundary curve between the two fields is reached, when the monoclinic and orthorhombic species crystallise together as separate phases. At the same time the two pyroxenes become progressively enriched in the $CaFe(SiO_3)_2$ and $FeSiO_3$ molecules respectively.

2. In the effusive stage of crystallisation, another condition ("condition B") prevails, and with rare exceptions the pyroxenic components of the residual liquid crystallise in a single pigeonitic phase without separation into two pyroxenes.

* Calculation from Hallimond's analysis of uniaxial enstatite-augite from Mull containing FeO = 27·77%, MgO = 12·69%, CaO = 3·80%, shows 10% of diopside in the pyroxene (Winchell, 1927, p. 181).

Thus "the pyroxenic components are only partially miscible in the intratelluric stage, while they are completely miscible in the effusive stage (with rare exceptions)."

The constant occurrence of "pigeonites" in the Bluff "norite" is thus in direct opposition both to the theory of Tsuboi and to the conclusion advanced by Barth. It should be noted, however, that Tsuboi himself thus recognises the possibility of exceptions to his generalisation:— ". . . it is not likely that the conditions A and B respectively correspond *always* to conditions in the intratelluric and in the effusive stages."

In a recent paper dealing with trends of differentiation in basaltic magmas, Kennedy (1933) has put forward an hypothesis which differs from the views of both Barth and Tsuboi. He recognises two independent fundamental basic magmas which he has termed respectively the "olivine-basalt" and the "tholeiitic" magma-types. In the former, early separation of olivine leaves the liquid enriched in lime so that a diopside-rich augite is the first pyroxene to crystallize. In the tholeiitic magma, however, no olivine, or in any case only a small amount, ever separates, so that the first pyroxene to crystallize belongs to the enstatite-augite series.

The clinohypersthene and enstatite-augite in the Bluff "norite" on this hypothesis would seem to be early products of crystallisation from a basic magma from which olivine had separated previously only in very small amount (seen from the rare occurrence of olivine in the Bluff rocks).

The occurrence of these two minerals in New Zealand rocks may be more widespread than has already been recognised, and in this respect it is interesting to note that Dr Marshall (1908, p. 363) records, in a mica-norite from the Darran Mountains, diallage with the "pleochroism and the schiller structure of hypersthene."

The writer wishes to express his thanks to Dr F. J. Turner for his assistance in the preparation of this note.

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Notes on New Zealand Lepidoptera

By EDWARD MEYRICK, B.A., F.R.S.

[*Read before the Wellington Philosophical Institute; received by the Editor, 12th December, 1933; issued separately, September, 1934.*]

CARADRINIDAE.

Aletia Lacustris, n. sp.

♂ ♀. 36-37 mm. Head, palpi, thorax grey, paler-mixed. Antennae ♂ serrate-dentate. Forewings somewhat elongate-triangular; grey with faint olive-greenish tinge; subbasal half-line edged dark fuscous spots at each extremity; first and second lines waved-dentate, interruptedly edged internally dark fuscous or blackish, sometimes indistinct, median obscure, darker grey, widely interrupted in disc; rounded orbicular and transverse-oblong reniform light grey, obscurely edged whitish laterally; a series of dark grey dots on veins beyond second line; subterminal obscure, whitish, interrupted, edged anteriorly with more or less dark fuscous spots; a terminal series of blackish marks: cilia dark grey mixed whitish. Hindwings grey becoming dark grey posteriorly; cilia grey-whitish, a more or less expressed grey subbasal shade.

4 examples taken at light on shores of Lake Rotorua, March 14, 1931 (Lawford White). Somewhat intermediate between *griseipennis* and *temenaula*.

HYDRIOMENIDAE.

Chloroclystis melanocentra, n. sp.

♂ ♀. 22-23 mm. Head, palpi, thorax grey mixed whitish. Antennae ♂ shortly and evenly ciliated. Forewings termen bowed, oblique; grey, striated blackish, somewhat mixed crimson, especially on third fascia and median and subdorsal portions of fifth; discal dot small, blackish; first, median, and second lines indicated by series of black dots; subterminal line waved, obscurely whitish; a fine blackish terminal line: cilia light grey speckled darker, obscurely darker barred. Hindwings termen excised beneath apex; pale greyish; striae and lines marked on dorsal third as on forewings, and faintly on median third, black dots of second line extending more than half across wing; terminal line and cilia as in forewings.

4 examples on slopes of Ben Lomond, Lake Wakatipu, at above 3000 feet, October 30, 1932 (Lawford White).

Xanthorhoe occulta Philp.

♀. 25 mm. Head and palpi as in ♂. Antennae filiform, simple. Forewings narrowly elongate-triangular, costa sinuate, apex very acutely produced, termen very oblique, sinuate; light rosy-brownish, sprinkled white and partially suffused light grey; lines formed of

white dots accompanied with some grey scales, as in ♂, but conforming to altered shape of wing: cilia red-brownish, tips white. Hindwings elongate-trapezoidal, apex very prominent, termen very oblique, somewhat sinuate (general form much as in some *Gelechiadae*); whitish-grey sprinkled grey, slightly reddish-tinged posteriorly; cilia pale grey-reddish, tips whitish. Neuration of forewings and hindwings essentially as in ♂, but necessarily compressed.

A single specimen of this extraordinarily formed insect sent by Mr Lawford White, who writes: "Taken on slopes of Ben Lomond, Lake Wakatipu, October 30, 1932; observed clinging to a tussock stem; unable to fly, could crawl about fairly rapidly with wings fluttering; altitude about 2500 feet." Three ♂ examples of *occulta*, taken in the same locality the same day, were also sent; I have compared these carefully with my own specimens of *occulta*, of which I possess a type received from Philpott himself, and five others from Mr Hudson, all six males, and they are unquestionably identical in structure and superficial characters alike. I am satisfied that this curious female is the other sex of these. There arises, however, the difficulty that Hudson, in his "Butterflies and Moths of New Zealand," figures on plate XIV both sexes of *occulta* as entirely similar in form of wing, and only differing in colour. I can only suggest (he does not say anything about the characteristic antennae) that he may have been misled as to the sex

PYRAUSTIDAE.

Hellula undalis Fab

One specimen sent by Mr Lawford White, who writes: "Taken by day flying among rushes on bank of New River about eight miles south of Greymouth, West Coast, and about three miles inland from sea, August 31, 1932. I have not seen any previous record of this species from New Zealand, but it is common through a large part of the world, including Australia and some of the Pacific islands; the larva is a garden pest, feeding on cabbage and turnip; it is therefore no doubt sometimes accidentally imported by man, but probably also migrates freely.

TORTRICIDAE.

– *Gelophaula praecipitalis*, n. sp.

♂. 24-25 mm Head, palpi, thorax dark fuscous mixed ochreous. Forewings somewhat elongate, scarcely dilated, costa gently arched, fold very narrow, hardly reaching ⅓, termen rounded, somewhat oblique; fuscous-grey, irregularly mixed ferruginous, thinly sprinkled black; some ferruginous suffusion beneath costa near base; cilia light grey. Hindwings dull orange, lighter towards base; a suffused dark fuscous apical fascia occupying nearly ⅓ of wing; cilia pale greyish, tinged ochreous towards tornus and dorsum; a grey subbasal line on termen.

2 examples, Mount Peel, 4000 feet, "rapidly flying over shingle fans on slopes" (Lawford White).

Tortrix ascomorpha, n. sp.

♀. 23-24 mm. Head, thorax pale ochreous, more or less suffused yellow. Palpi 3, whitish-ochreous, externally suffused yellow and irrorated fuscous. Forewings elongate-triangular, costa gently arched towards base and slightly near apex, apex obtuse, termen sinuate beneath apex, rather oblique; whitish-ochreous, slightly mottled yellow-ochreous and posteriorly somewhat strigulated fuscous; markings brownish largely suffused yellow-ochreous and irregularly mixed or marked fuscous especially on margins; a transverse streak limiting basal patch, acutely angulated in middle; central fascia rising from costa before middle, blackish on costal edge, at first rather narrow, oblique, below ¼ becoming much broader, anterior edge angularly prominent on fold and running to dorsum towards tornus, posterior edge with a projection above and lower portion produced in a curved fascia obliquely upwards to near termen above middle; costal patch moderate, flattened-triangular, containing one or two small costal spots of ground colour, its apex almost or quite touching projection of central fascia: cilia ochreous-yellowish. Hindwings whitish, some indistinct grey strigulae towards dorsal area; cilia whitish, tinged yellow round apex and upper part of termen.

Arthur's Pass, December, January (S. Lindsay); types in Canterbury Museum. Allied to *charactana* and *scruposa*, but very distinct. It is remarkable that this fine and noticeable species should now be discovered in a locality so much visited by entomologists during the past fifty years.

Gasteropods new to the New Zealand Fauna; with descriptions of Six New Species and a New Subspecies.

By A. W. B. Powell, Auckland Museum.

[*Read before Auckland Institute, August 29, 1933; received by Editor, August 31, 1933; issued separately September, 1934.*]

Genus *Atalacmea* Iredale 1915.

Type (original designation). *Patella unguis-almae* Lesson 1830 (= *fragilis* Sowerby 1823).

Atalacmea multilinea n. sp. Figs. 1, 3.

Shell small, depressed, ovate, apex at anterior ninth, rather pointed and directed forwards. Colour white, crowded with numerous narrow concentric brown lines, three to four per millimetre. Interior of shell glossy and coloured exactly as the exterior. This species differs from fragilis in being slightly more elongate-ovate, and not quite so depressed. Also the radial sculpture is almost obsolete and the colour pattern most distinctive. Comparing specimens of both species of similar size, *multilinea* has 25 concentric colour bands and *fragilis* only 12. Marwick's *A. elata* (1928, Trans. N.Z. Inst., vol. 58, p. 473) from the Pliocene of Titirangi, Chatham Islands, seems to stand nearer to this new species than does the common Recent *fragilis* The fossil species has somewhat similar, narrow, and numerous concentric colour lines, but differs from *multilinea* in being much more elevated and in having distinct radial sculpture.

Length, 8 75 mm.; width, 6·1 mm.; height, 1·75 mm. (Holotype).

Habitat: Kartigi Beach, North Otago, on under sides of stones at low tide. (Collected by the writer, January, 1928.)

The common *fragilis* (Fig. 2) was not found at Kartigi, although Oliver (1926, Trans. N.Z. Inst., vol. 56, p. 582) has recorded it from an adjacent locality, Shag Point. North of here, *fragilis* is common in both islands, but as I have no specimen from anywhere south of Kartigi, I am unable to say if the above new species is a regional one taking the place of *fragilis* for Otago.

Holotype: Presented to Auckland Museum.

Genus *Thoristella* Iredale 1915.

Type (original designation): *Polydonta chathamensis* Hutton 1873.

Thoristella chathamensis cookiana n. subsp. Figs. 10, 11.

Shell depressed conical, angled at the periphery; outline of spire evenly convex, the usual flattened shoulder and peripheral ridge being almost obsolete. Sculpture very regular, consisting of fine spiral cords with linear interspaces. There are 12 spirals on the penultimate whorl, 7 on the ante-penultimate, and about 29 on the body-whorl and base. The whole surface of the post-nuclear whorls is crossed by dense axial growth-striae, which shows quite plainly

in the interstices, but not on the cords themselves. Whorls 5, including a small smooth protoconch of 1½ whorls. Umbilicus almost filled with callus, leaving only a shallow pit.

Height of spire about equal to that of the aperture. Colour greenish-buff, the upper surface irregularly marked with radial blotches of dark-grey. Two of the cords of the spire whorls are coloured stronger than the rest. On the first post-nuclear whorl these cords are bright red, but the colour gradually changes to dark grey over the succeeding whorls, and finally loses its definition just before the body-whorl is reached. On the base there are no colour blotches, but the cords are intermittently marked with dark grey. Umbilical area and pillar white to pale buff, interior of aperture irridescent.

Height, 4·25 mm.; diameter, 6 mm. (Holotype).

Holotype: Presented to Auckland Museum.

Habitat: Island Bay, Wellington, under stones at low tide (type). Collected by the writer January 26, 1927. Goose Bay, Kaikoura, collected by the writer January, 1928.

The species is characterised by its fine regular and numerous spiral cords, and evenly conical spire with obsolete shoulder and no peripheral ridge.

Genus *Estea* Iredale 1915.

Type (original designation): *Rissoa zosterophila* Webster.

Estea semisulcata (Hutton 1885).

This species, originally described from the Wanganui Pliocene, is now known to the writer from Recent localities. Specimens from off the western coast of the Great Barrier Island in 6–10 fathoms and another from 20 fathoms off the Little Barrier Island have been compared with Castlecliff fossils and are found to be identical. The colour as shown by these living specimens is buff, with the spire whorls tinged with reddish-brown.

Genus *Roya* Iredale 1912.

Type (by monotypy): *Roya kermadecensis* Iredale.

Roya sp.

A single well-preserved specimen from shell-sand at Tom Bowling Bay is only half-grown. It is very close to the Kermadec Island genotype, but adult specimens are required before the specific identity of the New Zealand shell can be determined.

The New Zealand Recent occurrence of this genus is mentioned as Marwick (1931, N.Z. Geol. Surv. Pal. Bull. No. 13, p. 85) has previously recorded the genus from the New Zealand Tertiary, and has at the same time expressed a little uncertainty concerning the accuracy of his generic placing.

Genus *Polinices* Montfort 1810.

Type (original designation): *Polinices albus* Montfort
(= *Natica mammillaris* Lamk).

Polinices simiae (Deshayes 1838).

This widely distributed species must now be added to the New Zealand faunal list, as four dead shells, collected at different times, have been picked up at Cape Maria van Diemen by Mr F. Young, the principal keeper.

The Cape Maria specimens are inseparable from Kermadec Island examples which have been determined as *simiae* by Iredale (1910, Pro. Mal. Soc., vol. 9, p. 71).

The original locality of the type of *simiae* is uncertain. Favanne and Chemnitz quoted "New Zealand," but Hedley has rejected this original locality reference as "certainly wrong," and has suggested that it "probably indicates Cook's voyage as the source of the specimens, so Cooktown may have been the locality of the type." (Hedley 1924, Rec Aust. Mus., vol. 14, No 3, p 162)

Genus *Austromitra* Finlay 1926.

Type (original designation): *Columbella rubiginosa* Hutton

Austromitra erecta n sp. Fig. 12.

Shell similar to *rubiradix* Finlay 1926, but more solidly built, proportionately wider, with a shorter spire and heavy flat-topped spiral ridges in place of fine spiral grooves. Apart from two strong spiral ribs proceeding from about the uppermost plait, the rest of the pillar and fasciole area is without definite sculpture, being almost smooth. The colour is identical with that of *rubiradix*, very dark purplish-brown, almost black, except for the pillar and fasciole, which is reddish-orange. Whorls about five, protoconch eroded. Spire less than height of aperture. Whorls slightly shouldered, angle at three-fifths height of whorl. Sculpture of spire whorls consisting of low, broad, flat-topped spiral ridges, with slightly narrower interspaces, crossed by distant axial folds. There are three spirals on the spire whorls, situated below the angle, and on the body-whorl and base there are nine. The axials number eleven on the penultimate, but on the body-whorl they become obsolete over the latter part. The four pillar-plaits are slightly stronger than in *rubiradix*.

Height, 9 75 mm ; diameter, 4·75 mm. (Holotype).

Holotype: In writer's collection, Auckland.

Habitat: Taupo Bay, Whangaroa. (Collected by Mr W. La Roche 1924.)

Genus *Buccinulum* Swainson 1837.

Subgenus *Euthrena* Iredale 1918.

Type (original designation): *Fusus vittatus* Quoy and Gaimard.

Buccinulum (Euthrena) suteri n. sp. Fig. 6.

Shell small, fusiform, and solid; sculptured with prominent spiral ridges and axial costae. Whorls 4¾ plus typical *Euthrena* type of protoconch of two whorls: tip smooth, followed by a half-whorl of axial ridges and another half-whorl reticulated by four

spiral riblets. Post-nuclear whorls prominently sculptured with broad flattened spiral cords having linear interspaces. There are four spiral cords on the upper whorls, five on the penultimate, and seventeen on the body whorl and base. Immediately below the suture there is a moderately wide, depressed band that is devoid of spiral cords, but bears three or more weak spiral threads. Axial costae eleven per whorl, broad and rounded, with narrow interspaces, not extending above over the subsutural band nor below on to the base. Spire tall, a little more than height of aperture plus canal. Aperture small, ovate, produced below into a short open canal Outer lip thick, denticulate within Inner lip with a distinct denticle above near the posterior notch, and two inconspicuous small ones below near anterior canal The holotype is light brown with the spiral cords irregularly blotched with dark reddish-brown. The normal colouration, however, is the top half of the spire whorls and a broad band on the base, white; the rest of the shell including the fasciole with the spirals marked out in dark reddish-brown.

Height, 15 25 mm.; diameter, 7 mm (Holotype).

Holotype: In writer's collection.

Habitat: Whangaroa Harbour in 10 fathoms (Mr W La Roche 1922); Bay of Islands (Suter Collection, Wanganui Museum); Cape Palliser (Rev. W H. Webster Collection, Auckland Museum)

This species is allied to *robustum* Powell 1929 and *colensoi* (Suter 1908), but differs in being much more slender and in having more numerous spiral cords.

The specimens in the Suter Collection are labelled *Trophon paivae* Crosse, but there is also in this collection a photograph of one of these specimens, on the back of which is pencilled, "*Cantharidus andersoni* Suter Holotype × 3." The *Cantharidus* is evidently a *lapsus calami* for *Cantharus*, the genus in which Suter placed his allied species *colensoi*.

Although this species has been labelled *Trophon paivae* by Suter, the shells are very discordant with his description and nothing like his figure of that species Further, Iredale (1915, Trans. N.Z. Inst., vol. 47, p. 471) has pointed out that Suter's description does not apply to the type of *paivae*, and he has proposed the new name *Xymene quirindus* for Suter's shells. However, as no type was cited, and Suter's *paivae* was without doubt based upon a composite description, Finlay's (1926, Trans N.Z. Inst., vol. 57, p. 421) rejection of Iredale's *quirindus* as indeterminable is well justified

Genus *Iredalula* Finlay 1926.

Type (original designation): *Bela striata* Hutton

Iredalula venusta n. sp. Fig. 9.

Shell moderately large, elongate, subcylindrical. Spire tall, one and one-third times height of aperture plus canal. Whorls 7 plus typical protoconch of 3 whorls, tip small, inrolled, smooth, remainder faintly shouldered. At first the protoconch is smooth, but gradually

spiral cords develop and on the third whorl number eight. Also over the latter half of the third whorl the spirals are crossed by distinct thin axials. Post-nuclear whorls narrowly shouldered; sculptured below this shoulder with prominent flat-topped raised spiral cords. The spirals number eight on the upper spire whorls, but increase to nine on the penultimate, and there are about 29 on the body whorl from the suture to the fasciole. The spiral sculpture continues over the rounded fasciole, but is much finer, closer, and less distinct. The intercostal spaces vary in width from a little less than the width of the cords on the upper whorls to a little more than their width on the upper portion of the body-whorl. Over the basal portion of the body-whorl the interspaces become gradually less and less until they are almost linear near the fasciole. Aperture elongate, narrow, contracted below into a short, open, weakly notched and slightly reflexed canal which is inclined to the left and bent backwards slightly. Interior of aperture and perietal wall smooth and polished. Colour pale buff.

Height, 23·75 mm.; diameter, 8 mm. (Holotype).

Holotype: In writer's collection, Auckland Museum.

Habitat: Off Cape Campbell in 40–60 fathoms, Marlborough. Obtained from the s.t. "Futurist" by Mr H. Hamilton, April, 1926. This very distinctive species is allied to *Pleurotoma (Hemipleurotoma) alticincta* Murd. and Sut. 1906, from 110 fathoms off the Great Barrier Island. The Cape Campbell species differs in having just double the number of spiral cords.

Genus *Liratilia* Finlay 1926.

Type (original designation): *Daphnella conquisita* Suter.

Liratilia subnodosa n. sp. Figs. 4, 5.

Shell small, robust, fusiform. Spire tall, a little higher than height of aperture. Whorls angled at the middle, 6, including conical protoconch of two smooth whorls. Sculpture consisting of weak flattened spiral cords separated by linear interspaces, and with a few blunt nodulous axials which are distinct at the angle, but rapidly diminish both above and below it. On the spire whorls there are nine spiral cords on the penultimate whorl in the holotype and 9–11 in paratypes. On the body-whorl and base there are 23 spirals. The axials number 10 per whorl. Aperture long and narrow, sides parallel medially, angled above and weakly notched below. Outer lip thickened within, bearing five apertural tubercles, of which the uppermost is by far the strongest. Ground colour pinkish-buff, irregularly mottled with light brown. Protoconch and interior of aperture uniformly light brown. Some paratypes are white, mottled with a dark reddish-brown.

Height, 7 mm.; diameter, 3·3 mm. (Holotype).

Holotype: Presented to Auckland Museum.

Habitat: Taupo Bay, Whangaroa (on under sides of stones at low tide. Mr W. La Roche).

Fig. 1.—*Atalacmea multilinea* n. sp. (Holotype), dorsal, 8·75 mm. x 6 1 mm.
Fig. 2.—*Atalacmea fragilis* Sowerby. Kaikoura Coast.
Fig. 3.—*Atalacmea multilinea* n. sp. (Holotype), ventral.
Fig. 4.—*Liratilia subnodosa* n. sp. (Holotype), 7 mm x 3·3 mm
Fig. 5.—*Liratilia subnodosa* n. sp. (Paratype).
Fig. 6.—*Buccinulum (Euthrena) suteri* n. sp. (Holotype), 15·25 mm. x 7 mm.

Fig. 7.—*Antizafra vivens* n. sp. (Holotype), 12 mm. x 5·25 mm.
Fig. 8.—*Antizafra vivens* n. sp. (Holotype)
Fig. 9.—*Iredalula venusta* n. sp. (Holotype), 23·75 mm. x 8 mm.
Fig. 10.—*Thoristella chathamensis cookiana* n. subsp. (Holotype), 4·25 mm. x 6 mm.
Fig. 11.—*Thoristella chathamensis cookiana* n. subsp. (Holotype).
Fig. 12.—*Austromitra erecta* n. sp. (Holotype), 9·75 mm. x 4·75 mm.

This new species resembles Murdoch and Suter's "*Pleurotoma (Leucosyrinx)*" *eremita* 1906, which is the only *Liratilia* previously known which has axials in addition to the normal spiral sculpture. From *eremita*, which is from 110 fathoms off the Great Barrier Island, the Whangaroa littoral shell differs in being less elongate and in having fewer and more persistent axials, which extend over the body-whorl. In *eremita* the axials occur only on the upper-spire whorls.

Genus *Antizafra* Finlay 1926.

Type (original designation): *Columbella pisaniopsis* Hutton.

Antizafra vivens n. sp. Figs. 7, 8.

Shell large, strong, fusiform. Spire slightly higher than aperture. Whorls 7, including an elongate-conic protoconch of two smooth whorls. Outline slightly concave above, much inflated medially, and contracted basally. Post-nuclear whorls sculptured with prominent axials and interstitial spirals. The axials are broad and rounded and extend from suture to suture on spire whorls, but become obsolete over the base. They number 16 on the body-whorl and 15 on the penultimate. The spirals are broad and flat and are rendered conspicuous only by the deeply scored linear interspaces. There are four of these flattened spirals on the spire whorls, and the body-whorl has in addition to these ten spiral ribs on the anterior end, six of which are closely spaced on the fasciole. The other four spirals are much more widely spaced (the interspaces equalling the width of the ribs), and these are situated immediately above the fasciole. Between the upper spirals and the basal series about one-third of the body-whorl appears to be smooth, but under a lens, and with lateral lighting, five almost obsolete spirals are indicated by exceedingly fine linear grooves. Aperture typical, rhomboidal in shape, produced below into a short, wide, slightly reflexed, and shallowly notched canal. Outer-lip straight, sharp, and thickened within, bearing five denticles, strongest above and becoming weaker in descending order. Columella short and straight and with a distinct basal fold. Colour uniformly light yellowish-brown, except for the apical whorls, which are tinged with pink.

Height, 12 mm.; diameter, 5 25 mm. (Holotype).

Habitat: Whangarei Heads in 4 fathoms (Captain J. Bollons).

Holotype: In writer's collection, Auckland.

This species is nearest allied to Marwick's *Anachis speighti* (1924, Trans. N.Z. Inst., vol. 55, p. 199) from the Pliocene of Petane, Hawke's Bay. Two other closely allied species occur at the same locality, and the three have been separated by Finlay (1926, p. 431) under a new genus *Antizafra*. From *speighti* the Recent species differs in larger size, greater inflation, and still further reduction of the spiral sculpture, the clathrate effect of the genotype being almost lost.

The weakening of the spirals in *vivens* brings this species near to *Zafra*, but the type of that genus, which has not been figured, is apparently without spiral sculpture, apart from oblique grooves on the anterior end.

Genus *Philine* Ascanius 1772.

Type ( ) *Philine aperta* Linn.

Philine angasi Crosse and Fischer 1865.

This species name has appeared in our faunal lists before (Hutton 1873, Cat. Tert. Moll. N. Zeal., p. 53, and 1878 Journ. de Conch., p. 41), but these records have been rejected by Suter (1909, Proc. Malac. Soc., vol. 8, p. 257) and the New Zealand species so identified described as a new subspecies, *Philine constricta auriformis.*

However, the writer finds that the Australian *P. angasi* really does occur in the waters of northern New Zealand There is no mistaking *angasi,* for it is a large mollusc, one of the New Zealand specimens being 78 mm. x 41 mm. with a shell 26 mm. x 20 mm. Further, the shell of *angasi* can be distinguished at any stage by its smoothness, that of *auriformis* being spirally striated.

The writer has a spirit specimen of an adult *angasi* from Mansion House Bay, Kawau, and there are in the late Rev. W. H. Webster's collection, now in the Auckland Museum, shells and a stomach-plate from Orua Bay, Manukau Harbour. Unfortunately, in the case of Webster's specimens, Orua Bay and Tasmanian examples are mounted in the same box with no satisfactory indication of the respective localities of each specimen

Description of Plates.

Plate 21.

Fig 1.—*Atalacmea multilinea* n. sp. (Holotype), dorsal, 8.75 mm. x 6.1 mm.

Fig. 2.—*Atalacmea multilinea* n. sp. (Holotype), ventral.

Fig. 3.—*Atalacmea fragilis* Sowerby. Kaikoura Coast.

Fig 4.—*Liratilia subnodosa* n sp. (Holotype), 7 mm. x 3.3 mm.

Fig 5.—*Liratilia subnodosa* n. sp. (Paratype).

Fig 6.—*Buccinulum (Euthrena) suteri* n. sp. (Holotype), 15.25 mm. x 7 mm.

Plate 22.

Fig. 7.—*Antizafra vivens* n. sp (Holotype), 12 mm. x 5.25 mm.

Fig. 8.—*Antizafra vivens* n. sp. (Holotype).

Fig. 9.—*Iredalula venusta* n. sp. (Holotype), 23.75 mm. x 8 mm.

Fig. 10.—*Thoristella chathamensis cookiana* n. subsp. (Holotype), 4.25 mm. x 6 mm.

Fig. 11.—*Thoristella chathamensis cookiana* n. subsp. (Holotype).

Fig. 12.—*Austromitra erecta* n. sp. (Holotype), 9.75 mm. x 4.75 mm.

Schists from the Forbes Range and Adjacent Country, Western Otago

By F. J. TURNER, Otago University.

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INTRODUCTION.

FOR several years the writer has been investigating problems connected with the schists of Central and Western Otago and Southern Westland. During this time it has become increasingly clear that questions relating to the nature, origin, and age of these rocks can be answered definitely only when details of their petrology and structure over wide areas are known. It is therefore proposed to record the results of petrographic examination of schists from different parts of this region, especially the western portion where the relation to the adjacent unaltered rocks may be observed.

During the past three summers, members of the Otago Section of the New Zealand Alpine Club have been engaged in climbing and exploring the high peaks in the neighbourhood of the Dart and Rees Valleys, north of Lake Wakatipu[1]. As this country is difficult of access and geologically unexplored, climbing parties were asked to collect rock specimens *in situ* where possible, and in this way twenty-three accurately localised specimens have been obtained from various points on the Forbes Range, the northern end of the Richardson Range, and the intervening valley of the Rees. This paper is based upon a petrographic examination of these specimens, and owing to the incomplete data available, is itself admittedly incomplete.

The writer wishes to record his sincere thanks to Messrs O. V. Davies, K. Grinling, A. Jackson, and S. Russell, who collected the material and made it available for description. At the same time, the hope is expressed that further collecting will be carried on in the near future by climbers visiting the adjacent mountain ranges of this inaccessible region.

PETROGRAPHY.

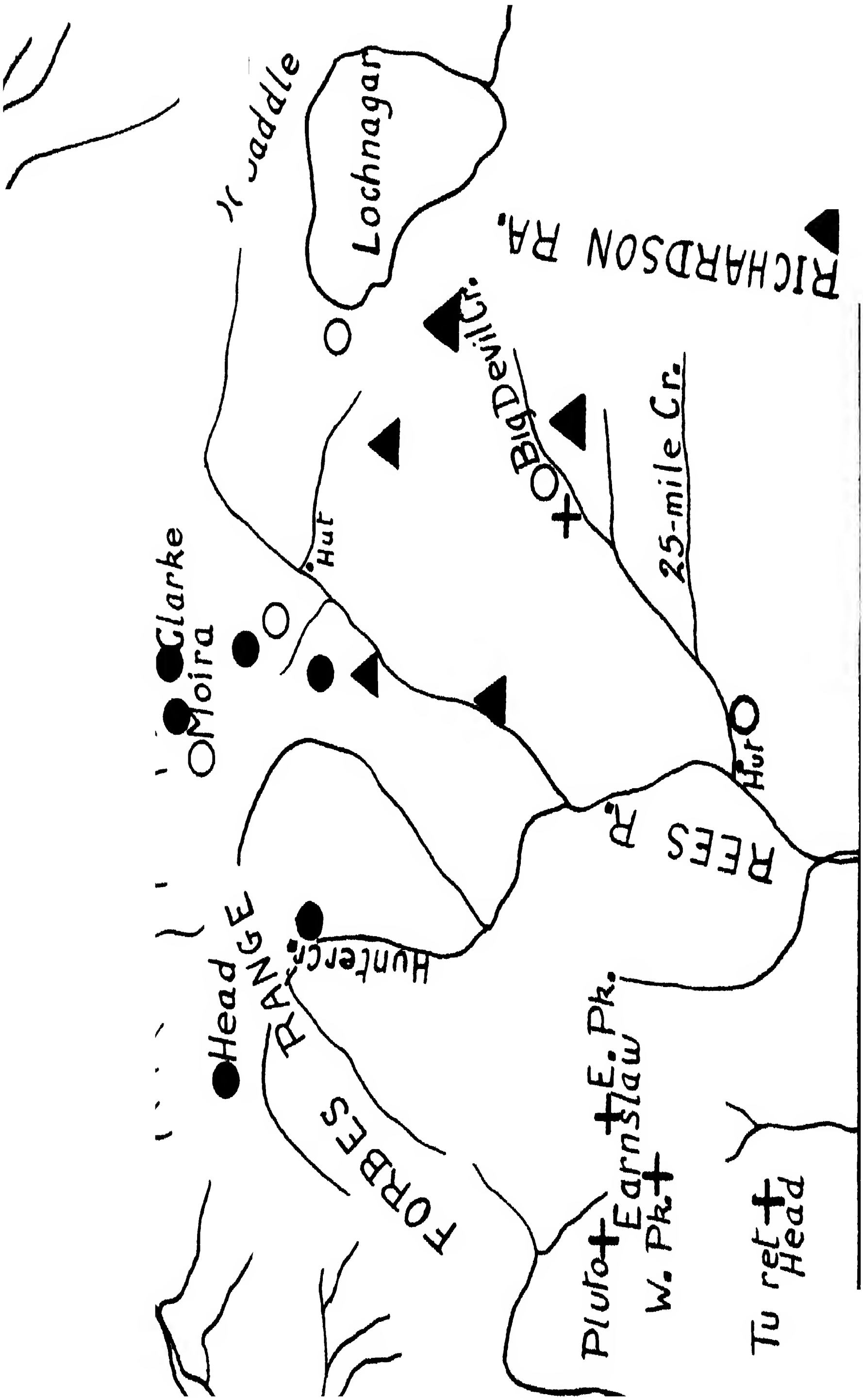
(1) *Albite-quartz-epidote-chlorite-phyllites.*

The rocks classed as phyllites are represented by five specimens from the southern portion of the area under consideration:—

[1a]No. 1469, Big Devil Creek, altitude 4000 feet.
No. 1487, Summit of Pluto, Forbes Range.
No. 2088, East Peak of Earnslaw, Forbes Range.
No. 2089, Turret Head, Forbes Range.
No. 2090, West Peak of Earnslaw, Forbes Range.

[1] See *N.Z. Alpine Journal*, vol. 4, pp. 191-205; vol. 5, pp. 62-70, 190-200.

[1a] Numbers refer to specimens and sections in the Geology Department, Otago University.


Lochnagar
RICHARDSON RA.
Big Devil Cr.
25-mile Cr.
Hut
Clarke
Moira
Hut
REES R.
Hunter Cr.
Head
RANGE
FORBES
E. Pk.
Earnslaw
W. Pk.
Pluto
Turret Head

In hand-specimen these rocks are fine-grained, highly fissile, grey slaty phyllites in which schistosity is highly developed, though true foliation[2] is completely absent. In some cases (e.g., Nos. 2088, 2090) relatively coarse quartzo-feldspathic veins 1 cm. to 2 cm. in width cut across the schistosity planes.

Microscopically the chief constituents are seen to be albite, quartz, epidote, and chlorite, which together build up a fine-grained aggregate of crystalloblastic grains, averaging 0·01 mm. to 0·03 mm. in diameter. These are usually accompanied by small but never important amounts of finely flaky sericite, while in two specimens (Nos. 1469, 1487) pale green to colourless actinolite is a minor constituent. Owing to the small size of the grains, the properties of the albite, other than the positive sign and distinctly low refractive index (always less than for Canada balsam), could not be determined, so that the exact composition has not been ascertained. The epidote takes the form of minute xenoblastic yellowish grains, usually aggregated into clusters, and is invariably a highly birefringent ferruginous variety, though in one instance (No. 2088) rare grains of clinozoisite are also present. The chlorite is a pale green, very poorly birefringent type with positive elongation and negative optic sign, usually showing the characteristic anomolous blue interference tint when viewed between crossed nicols. Following Winchell's (1927, p. 379) classification it may be classed as negative pennine or delessite.

Colourless sphene in rounded drop-like granules is a constant and sometimes plentiful accessory; iron-ores are scarce or absent and may be partially replaced by sphene or altered to limonite; rarer minor constituents are calcite (No. 1487), apatite (No. 2089), and tourmaline (No. 2089). The latter mineral is a pale variety, pleochroic from colourless to rather pale blue, and occurs in relatively large perfectly idioblastic prisms ranging up to 0.2 mm. in length.

In addition to the recrystallised minerals described above, several of the phyllites (e.g., Nos. 1469, 1487) contain large relict grains, ranging between 0·2 mm. and 0·8 mm. in diameter, scattered plentifully through the fine-grained reconstituted base. In No. 1469 these relict constituents include brown and green hornblendes, quartz, plagioclase, and rare ilmenite. The amphiboles show partial conversion to mixed chlorite and actinolite. The quartz is slightly strained, but the porphyroclasts of feldspar have suffered considerable crushing, and have the composition of albite. The larger grains of ilmenite are rimmed with dense granular sphene. In No. 1487 the residual grains make up as much as 25% of the total composition and include both quartz and plagioclase. The former occurs as large clear grains with faintly undulose extinction, which have undergone partial marginal granulation. The plagioclase is now albite containing less than 5% of anorthite; it has usually recrystallised as augen and lenticles of small clear granules, but in some cases the twin lamellae of the original relict grain may still persist. In

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[2] The distinction between schistosity and foliation is emphasised by Harker (1932, p. 203).

No. 2089 the only indication of the initial clastic structure is the presence of small lenticles and patches of granular quartz or feldspar which do not exceed 0·2 mm. in diameter. In Nos. 2088 and 2090 relict minerals are absent.

The quartzo-feldspathic veins cutting the schists obliquely to the schistosity are well shown in No. 2088. The vein-material consists mainly of quartz (90%) and albite (10%), together with rare, vermicular, transversely fibrous masses of pale yellowish-green chlorite. The quartz and albite appear in the first place to have been coarsely crystalline; but the grains for the most part have been broken down by subsequent shearing, to a mosaic of irregular granules (averaging 0·02 mm.) which enclose partially sheared porphyroclasts ranging from 0·5 mm. to 1 mm. in diameter.

(2) *Quartz-albite-epidote-chlorite-schists*

The rocks of this group include the following specimens.—

No. 1466, Ridge 4 miles South of Mount Clarke, Forbes Range.

No. 1468, Twenty-five-mile Creek, Rees Valley.

No. 1482, Big Devil Creek, altitude 4000 feet.

No. 1486, Summit of Moira, Forbes Range

No. 2068, Little Lochnagar Peak, N. end Richardson Range

Macroscopically they are thoroughly schistose, finely foliated, dark greenish-grey schists, consisting of thin laminae, alternately rich in quartz and feldspar on the one hand, and in epidote and chlorite on the other. In section they are seen to be completely reconstituted rocks with an average grain-size of between 0·1 mm. and 0·5 mm. Quartz and albite ($Ab_{98}An_2$ to $Ab_{95}An_5$) together make up nearly 75% of the total composition, the former mineral usually being somewhat in excess of the latter. Chlorite (delessite) and an epidote mineral typically are both sufficiently plentiful to rank as essential constituents, though the proportion of either mineral may in particular instances fall below 10%. Small amounts of sericite are invariably present, while sphene and iron ore are constant accessories. In one specimen (No. 1486) there are scattered small prisms of nearly colourless actinolite, while in two others (Nos. 1468 and 1482) a brown pleochroic mineral, referred to the stilpnomelane group has been formed at the expense of the chlorite.

In mineralogical composition the quartz-albite-epidote-chlorite-schists thus resemble the phyllites described in the previous section. They differ from the latter, however, in coarser grain-size, absence of relict minerals or structures, and development of a perfect foliation, so that they would seem to have undergone metamorphism of a somewhat higher grade than the phyllites. No. 1486 is a relatively fine-grained schist (average grain-size = 0·05 mm. to 0·1 mm.) with indistinct foliation, and should perhaps be regarded as a transition type between the two groups.

No. 1468 may be described in greater detail, as typical of this group of schists. The average grain-size is 0·1 mm. to 0·2 mm. The constituents are albite 45%[1], quartz 25%, chlorite 10% to 15%, epidote 10%, sericite 2% to 5%, stilpnomelane mineral 3% to 5%, magnetite 1% and accessory sphene. The albite occurs as clear usually untwinned grains, the composition of which, as indicated by the optical properties, is not more calcic than $Ab_{98}An_2$ (in sections perpendicular to Z, X to 001 cleavage = 21°; in sections perpendicular to X, Z to 001 cleavage = 14°; sign +; refractive indices greatly less than for Canada balsam). The quartz is in irregular grains showing undulose extinction. The chlorite is of the type classed by Winchell (1927, p. 379) as delessite; it is distinctly pleochroic from pale yellow (X) to moderately deep green (Y and Z), very poorly birefringent, and shows the anomolous blue interference tint between crossed nicols. The epidote mineral is clinozoisite with a birefringence varying between 0·005 and 0·008, and typically occurs as idioblastic prismatic crystals, often crowded with or closely associated with clouds of magnetite dust. Small flakes of sericite are unevenly distributed throughout the section and occasionally are interlaminated with the chlorite.

A deep golden-brown strongly pleochroic mineral of micaceous habit occurs as irregular patches and well-defined laminae in the larger crystals of chlorite (Pl. 23, Fig. 3), and is obviously a derivative of the latter mineral. The pleochroism follows the scheme:

$$\begin{aligned} X \quad &= \text{golden brown,} \\ Y = Z &= \text{deep golden brown,} \\ X < Y &= Z. \end{aligned}$$

It is uniaxial and optically negative (in No. 1482 biaxial with a very small optic axial angle), with positive elongation, and a birefringence of about 0·015 to 0·020 as measured by comparison with quartz and albite. The mineral thus closely resembles biotite, from which it differs, however, in its distinctly lower birefringence (this property being approximately constant in all specimens of this mineral so far examined). Further, it appears in every instance to have formed directly from chlorite and is totally independent of the presence of sericite, though the latter mineral may frequently be observed in direct contact with unaltered chlorite. The optical properties agree well with those of the ferruginous members of the stilpnomelane group. Thus Winchell (1927, p. 371) records jefferisite as having identical properties except that the absorption is not so strong (X = colourless, Y = Z = pale brown). Again, Walker (1924, pp. 39, 40) has described a ferric "chlorite" allied to jefferisite as having a high double refraction and yellowish colour. Stilpnomelane itself has similar properties to those of the present mineral, but the birefringence is normally much higher (Hallimond,

[1] Percentages in all cases are rough estimates based on microscopic inspection.

1924, p. 193); nevertheless, Shannon (1920) records a dark brownish green stilpnomelane with a birefringence of 0·015, so that this property would appear to vary considerably within this series.

(3) *Actinolite-bearing Albite-epidote-schists.*

The rocks grouped under this heading are confined to the north-western quadrant of the area under consideration. The following specimens are included:—

No. 1477, Ridge south of Clarke, Forbes Range.

No. 1478, Ridge south of Clarke, Forbes Range.

No. 1479, Pyramid Saddle, ½ mile west of Clarke.

No. 1480, Summit of Clarke, Forbes Range.

No. 1484, Hunter Creek, Upper Rees Valley.

No. 1485, Summit of Head, Forbes Range.

In hand-specimen the albite-epidote-schists are fine-grained, grey schistose rocks, distinctly foliated usually on an exceedingly fine scale. Typically neither schistosity nor foliation is so perfectly developed as in the schists of the previous group. Quartzo-feldspathic veins sometimes cut sharply across the direction of schistosity.

Microscopically the rocks consist mainly of albite and an epidote mineral, which together make up between 70% and 90% of the total composition, quartz being unimportant or completely lacking. In such rocks actinolite is constantly present in amounts between 1% and 15%, in contrast with the general absence of this mineral in schists belonging to the other groups described from this region. Chlorite (delessite) and sericite typically occur in minor quantities only, though rarely the percentage of either mineral may reach 10% or more (e.g., chlorite in No. 1484; sericite in No. 1477). Sphene and iron ores are the commonest accessories; the yellowish-brown stilpnomelane mineral noted above is present under similar conditions in two sections (Nos. 1479, 1485), while pale bluish-green and brown tourmaline is locally abundant in No. 1478 (Pl. 23, Fig. 1).

The epidote varies in composition from a highly ferruginous yellowish variety with a birefringence of 0·03 to 0·04 (Nos. 1477, 1478, 1479) to less strongly birefringent colourless types approaching clinozoisite (Nos. 1480 and 1484). Indeed, the composition may vary within the limits of a single section. The albite is very poor in anorthite and is never more calcic than $Ab_{95}An_5$. The remaining minerals have the same properties as in the schists described in the previous section.

No. 1479 is typical. It is a completely crystalloblastic rock consisting of albite 40%, epidote 40%, actinolite 10%, chlorite (showing transition to "stilpnomelane") 5%, sericite 2% to 3%, quartz 2%, and accessory sphene and magnetite. The average grain-size is 0·05 mm. to 0·1 mm. The exact composition of the albite could not be determined owing to lack of suitable sections, but the anorthite content is not greater than 5%. The epidote occurs in

colourless grains and idioblastic prisms with a birefringence of 0·04 (corresponding to 28% of the ferruginous epidote molecule and 13% Fe_2O_3). There are plentiful parallel slender prisms of colourless actinolite 0·3 mm. or 0·4 mm. in length, with well-marked cross-fracture.

(4) *Sericitic Schists.*

The following specimens of sericitic schists are recorded:—

No. 1470, 4 miles above Twenty-five-mile Creek, Rees Valley.

No. 1483, Upper Rees Valley (6 miles above Twenty-five-mile Creek).

No. 2066, N. end of Richardson Range.

No. 2067, Spur between Big and Little Devil Creeks, Richardson Range.

No. 2069, 1½ miles west of Lochnagar, Richardson Range.

No. 2091, Lochnagar Peak, N. end Richardson Range

These localities all lie within the western half of the map.

Macroscopically these are highly schistose, well-foliated, greyish-green soft schists, with lustrous schistosity planes in the freshly broken specimen. As in the other schists of this area, quartzo-feldspathic veins may sometimes cut across the specimen transversely to the direction of schistosity and foliation.

As seen beneath the microscope the distinctive feature of the sericitic schists is the presence of plentiful sericite which usually makes up between 20% and 30% of the total composition. Quartz and albite together usually amount to about 40%, albite being on the whole the more abundant mineral of the two; whenever the composition of the latter is accurately determinable it lies between $Ab_{99}An_1$ and $Ab_{97}An_3$. Chlorite (delessite) is usually more plentiful than in the other groups of schists, though not invariably so. Poorly birefringent clinozoisite is always an essential constituent, and rarely is accompanied by small amounts of granular yellow epidote. Iron-ore is a constant accessory, typically in the form of clouds of dust-like particles concentrated in the clinozoisite-rich bands and intimately associated with that mineral. Sphene may sometimes be plentiful (Nos. 2069, 2091), but in other specimens is lacking. Less consistently developed minor constituents are the stilpnomelane mineral (Nos. 1483, 2066), actinolite (No. 1470), and calcite (No. 2091).

The average diameter of crystals and grains of the essential constituents ranges from 0·1 mm. to 1 mm., so that the sericitic schists typically are rather coarser in grain than the rocks of any of the other groups.

No. 2069 is a typical schist of this group, though the percentage of sericite is somewhat lower than usual. It is a relatively coarse-grained rock consisting of albite 30%, quartz 10%, sericite 15%,

chlorite 15%, clinozoisite 30%, iron ore 1%, and accessory sphene. The albite is almost pure, with an anorthite content of not more than 1%. (In sections perpendicular to X, Z to 001 cleavage = 15°; and Z to 010 twinning plane = 74°; in sections perpendicular to Z, X to 001 cleavage = 24°; optically +, refractive indices notably lower than that for Canada balsam.) The mica is sericite with a small optic axial angle; the chlorite is pale green nearly isotropic delessite. The epidote mineral is poorly birefringent (less than 0·01) colourless clinozoisite, occurring as stout idioblastic prismatic crystals, often charged with dusty inclusions of magnetite. Sphene occurs both as large irregular masses and swarms of minute granules. In addition to the clouds of magnetite dust already mentioned, there are scattered larger grains of iron-ore altered to limonite.

(5) *Quartz-sericite-epidote-schist.*

A single specimen (No. 1481, North branch Hunter Creek, Upper Rees Valley) among the material under consideration, falls into none of the four groups of rocks described above, and is therefore best placed in a separate class.

It is a fine-grained, highly schistose, well foliated, lustrous grey schist somewhat resembling the sericitic schists in general appearance, but not so coarse-grained. As seen beneath the microscope it is a completely crystalloblastic rock consisting of quartz 70%, pale greenish sericite 10%, clinozoisite and epidote 15%, pale green chlorite 3% to 5%, and accessory fine dusty magnetite and rare sphene. Though albite was carefully looked for, it appears to be quite absent.

(6) *Summary of Petrographic Characters.*

The criteria by which the various groups of rocks, just described, have been defined are firstly structural and secondly mineralogical. Under the first heading may be included such characters as coarseness of grain, degree of development of schistosity and foliation, and in a few cases persistence of relict grains of clastic origin. The mineralogical criteria mainly concern variations in the relative proportions of the various crystalloblastic constituents, rather than variations in the nature of the minerals themselves.

The grouping adopted above serves the useful purpose of demonstrating differences in chemical composition and to some extent in metamorphic grade, among the rocks under discussion. It also shows that there is a marked tendency for the development of several distinct assemblages of *essential* constituents. Nevertheless the boundaries between the various groups defined must not be regarded as sharply drawn, for some intermediate types are already known, and no doubt others will be recorded later when fuller data are available.

Though emphasis has so far been placed upon the petrographic differences that exist between the different groups, it is equally important to note certain constant characteristics that pertain to

all the rocks described, stamping them as members of a single rock-series, with a common tectonic and metamorphic history, and all of similar origin. Some of the most important of these constant characters may be summarised thus:—

(a) Schistosity is always well developed, and except in the finer-grained members there is also perfect foliation.

(b) The great majority of the rocks have been completely reconstituted, relict minerals being absent except in a few of the finer-grained phyllites.

(c) Strain structures, especially undulose extinction in the grains of quartz and albite, are common.

(d) Though there is a great variation in the proportions of the various minerals present, the actual assemblages of minerals, including accessory and minor as well as the essential constituents of the different rocks, is surprisingly constant Thus albite, quartz, an epidote mineral, chlorite, sericite, sphene, and magnetite are found in almost every specimen. Common but less frequently developed minerals are actinolite and a member of the stilpnomelane group, this latter being formed at the expense of chlorite. Still rarer accessories are tourmaline, calcite, and apatite. The optical properties of the chlorite are constant and conform to those given by Winchell for delessite. The albite is never more calcic than $Ab_{95}An_5$ and usually has a composition of about $Ab_{97}An_3$.

(e) In a number of specimens (belonging to all five of the above groups) veins of quartz and albite, accompanied by minor vermicular chlorite, cut the schistosity at high angles. The constituent minerals of these veins invariably show marked effects of cataclasis.

ORIGIN.

In a recent account of the schists and other metamorphic rocks from a region whose southern border lies some twenty miles north of that under present consideration, the writer (Turner, 1933) described a series of quartzo-feldspathic schists, the least metamorphosed members of which have many characters in common with those from the Forbes Range and surrounding country, though differing in petrographic detail. Indeed, the schists of the two areas are continuous with each other. The conclusion previously reached (Turner, 1933, pp. 214, 215, 220), viz., that the schists are the metamorphosed equivalents of greywackes, applies also in the present instance and need not be discussed further.

THE COURSE OF METAMORPHISM.

(1) *Nature and Grade of Metamorphism.*

It has already been shown (Turner, 1933, pp. 251-3) that the schists of western Otago and southern Westland owe their present condition to progressive dynamothermal metamorphism caused by

folding, combined with the contact effects of invading granitic batholiths in the deeper zones of intense alteration. The constant assemblage albite-quartz-epidote-chlorite-sericite-sphene which is so characteristic of the schists of the present area, places them all within the chlorite zone. In this zone, representing the lowest of the three grades of metamorphism so far recognised in the Otago-Westland region, and remote from the granites of the deeper zones, the metamorphism is almost purely of the dynamothermal regional type. Yet it should be noted that even here, as in the chlorite zone of Westland fifty miles north, the occasional presence of tourmaline bears witness to the passage of boric fluids emanating from the subjacent granite mass.

All the rocks described in this paper belong to Eskola's greenschist facies; furthermore, all belong to that sub-facies which Tilley (1924) recognised as characterised by chlorite-epidote-albite, in contrast with the hornblende-acid oligoclase-epidote sub-facies which corresponds to a slightly higher grade of metamorphism.[1] Nevertheless, slightly different grades of metamorphism may be recognisable even within tthe limits of a single zone, among rocks of the same facies, and the rocks under consideration afford a clear instance of this. Though it has not yet been found possible to subdivide the chlorite zone, it is nevertheless clear that the grade of metamorphism increases from south-west to north-east within the limits of the map. Thus the non-foliated, often incompletely reconstituted phyllites with a single exception are confined to the southern end of the Forbes Range, in the south-western corner of the map. While allowance must be made for initial differences in texture and composition, the phyllites undoubtedly represent a slightly lower metamorphic grade than do the coarser, well-foliated, completely reconstituted schists to the north and east. The presence of even less completely altered semischists and sheared greywackes still further to the south-west beyond the limits of the map (on the western side of the Dart Valley), lends further support to this view.

(2) *Mineralogical Changes.*

The mineralogical changes involved in the metamorphism may be summarised briefly as follows:—

(a) Clastic plagioclase breaks down to almost pure albite, with the liberation of lime and alumina which enter into the epidote mineral.

(b) Hornblende (in the one instance where relict grains of this mineral still persist) is transformed to a mixture of actinolite and chlorite, a reaction involving liberation of lime, alumina, and ferric iron, all of which enter into the epidote.

[1] To avoid confusion it should be noted that the writer, in a paper which has appeared since the present paper was submitted for publication, has suggested a slight modification of Tilley's scheme, though this is immaterial to the present discussion. (F. J. Turner, The Genesis of Oligoclase in Certain Schists, *Geol. Mag.*, vol. lxx, pp. 529-541, 1933.)

The actinolite-bearing schists are believed to owe their content of actinolite to similar replacement of now completely destroyed hornblende and probably pyroxene also. This lends further support to the suggestion recently advanced by the writer[1] that under some conditions actinolite may form from hornblende or pyroxene, even at the lowest grades of metamorphism within the chlorite zone.

(c) Though the transition was not actually observed, it is obvious that in some cases the original amphiboles and pyroxenes of the parent greywackes have broken down still further to a mixture of chlorite and epidote. As pointed out by Vogt (1927, p. 410) this involves the removal of a considerable amount of lime, some of which has been fixed in the present rocks as sphene and occasionally as calcite.

(d) Clastic ilmenite is replaced by sphene.

(e) In the fine-grained phyllites the epidote is a yellow, highly ferruginous variety occurring as xenoblastic grains and granular clusters. In the more coarsely crystalline schists of slightly higher grade the mineral has recrystallised, usually completely, as idioblastic prisms of colourless clinozoisite or more rarely as poorly ferriferous epidote. This may account for the clouds of magnetite dust that are frequently associated with or even enclosed by the clinozoisite. Progressive decrease in the iron-content of epidote with increasing intensity of metamorphism has been noted by various observers (e.g., Tilley, 1923, p. 185; Sugi, 1931; Turner, 1933, pp. 240, 243), usually, however, at higher grades of metamorphism than those with which we are at present concerned.

(f) Crystallisation of a brown pleochroic stilpnomelane mineral appears from the available literature to be a sufficiently unusual feature to deserve fuller comment.

The mineral was at first mistaken for biotite, which it closely resembles but for minor differences in the optical properties, especially a distinctly lower birefringence. However, both in the area under discussion and throughout an extensive region further south-west, the mineral in question appears in rocks representing an extremely low grade of metamorphism, whereas brown biotite is always developed only when a much more advanced grade is reached (e.g., Barrow, 1912, p. 2; Harker, 1932, p. 214; Turner, 1933, pp. 239, 240).[2] Finally, the characteristic mode of occurrence of the mineral in question, as a direct derivative of chlorite in no way dependent upon the presence or proximity of sericite, is itself strong evidence against identification as biotite.

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[1] Op. cit., *Geol. Mag.*, 1933, p. 534.

[2] The mineral is quite distinct from the green biotite that often makes an early appearance in green schists within the chlorite zone.

Hallimond (1924) has suggested that stilpnomelane may play an important part in schists originating by metamorphism of sediments containing abundant ferruginous chlorite but little sericite. According to Winchell (1927, p. 379), delessite such as that of the schists under discussion is a relatively ferruginous variety of chlorite. Comparison of the compositions of delessite and stilpnomelane as given by Winchell shows that the latter may well have originated by a change involving complete oxidation of the ferrous iron present in the chlorite. Possibly in the schists described above a further supply of available iron in the magnetite has also been utilised.

In conclusion, it may be noted that the presence of leverrierite, an aluminous member of the stilpnomelane group, as a crystalloblastic mineral in sericite-schists has been demonstrated clearly by C. S. Corbett (1925).

(3) *Structural Changes.*

Four successive stages of structural evolution may be recognised, characterised respectively by the following processes: Cataclasis of the original mineral grains, crystalloblastic growth of the reconstituted minerals, formation of transgressive quartzo-feldspathic veins, and finally a further cataclasis of the reconstituted minerals.

Judging from the persistence of strained, partially altered relict grains of clastic origin only in the fine-grained phyllites (the least metamorphosed rocks), reduction of grain-size by cataclastic degradation of the constituents of the original sedimentary rock is the main feature of the earliest stage in metamorphism. This purely mechanical effect is accompanied by complete chemical reconstitution of the rock, and simultaneous development of schistosity. Thus the initial coarse-grained greywacke is transformed into a phyllite consisting of an assemblage of minerals in mutual equilibrium under intense stress. It is of course probable that some of the phyllitic rocks owe their fine grain to correspondingly fine grain in the parent sediment, but in the majority of the cases examined, cataclasis appears to be the responsible factor.

The second stage (not shown in rocks from the south-western corner of the map) involves the crystalloblastic growth of the previously crushed, largely reconstituted mineral grains. By this process relict grains disappear as the new assemblage attains equilibrium, mineral grains increase in size, the grains of those minerals which are placed high in the crystalloblastic series (sphene, epidote, clinozoisite, actinolite) assume idioblastic outlines, and foliation is developed parallel to the schistosity by a process of metamorphic diffusion. The resultant rocks are schists as distinguished from the phyllites of lower grade. Sporadic introduction of tourmaline may be assigned to this stage. The orientation of the tourmaline prisms with their long axes in the plane of schistosity may be due to growth either under stress (compare Harker, 1932, p. 194) or according to Sander's principle of mimetic crystallisation after cessation of deformation (compare Knopf, 1933, pp. 461, 462).

Following upon the cessation of the above processes, which, taken in conjunction, constitute the main phase of metamorphism, comes a minor phase characterised by the formation of quartz-albite veins cutting transversely across the schistosity and foliation. The occurrence of similar veins is a familiar feature of a number of regionally metamorphosed areas. They are usually attributed (e.g., Tilley, 1923, pp. 194, 195, 204) to segregation of quartz and albite derived from the surrounding schist, under the influence of circulating waters after the cessation of metamorphism. This explanation accords well with the observed facts in the area under discussion. The fact that the veins run obliquely to the schistosity suggests that they were formed long subsequently to the main metamorphism, when a new system of stresses influenced the rock mass.

A final phase of relatively mild, purely dynamic metamorphism is clearly indicated by the marked cataclastic effects shown by the vein material. The undulose extinction so frequently observed in the constituent grains of the schists themselves should probably be correlated with this final movement.

(4) *Evidence of Repeated Metamorphism.*

The writer has recently discussed the available evidence as to the period at which metamorphism of the schists of Otago and Westland took place, and has advanced the tentative view that the main metamorphism occurred in Palaeozoic times, and was followed by relatively mild epi-zone changes accompanying the Hokonui orogeny of the Early Cretaceous (Turner, 1933, pp. 255, 256). On this assumption, while the main metamorphism of the rocks described in this paper may be assigned to the Palaeozoic Era, the writer sees in the later phases of quartz-albite veining and minor cataclasis, the much less pronounced changes accompanying the Hokonui deformation.

It must be borne in mind that the effects of polymetamorphism of this type, where both phases of metamorphism have been of relatively low grade, are difficult to detect with certainty, for the second metamorphism is unaccompanied by retrogressive mineralogical changes, and the evidence is purely structural. In emphasising the difficulty of interpreting evidence of this type Eleanora Knopf (1933, p. 462) writes as follows: ". . . An area of phyllonites may show more than one phase of deformation, yet these different stress conditions may have belonged to one and the same period of progressive metamorphism. But, on the other hand, the regional study may show up in some rocks relics of a higher rank metamorphism than the present, which would indicate that the recorded changes in stress are associated with polymetamorphism." Thus while the structural evidence recorded above indicates pronounced changes in stress conditions during the metamorphic history of the present rocks, this taken alone does not necessarily imply the existence of more than one metamorphism. But taken in conjunction with the

marked evidences of retrogressive metamorphism observed in southern Westland (Turner, 1933, pp. 249-251), it does afford strong corroboration to the view that there has been widespread repeated metamorphism in the Otago-Westland region.

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FIG. 1. Large idioblastic prisms of tourmaline in actinolite-bearing albite-epidote-schist (No. 1478).

2.—Acicular prisms of actinolite, and granular epidote in actinolite-bearing albite-epidote-schist (No. 1480).

FIG. 3.—Quartz-albite-epidote-chlorite-schist (No. 1468) showing development of stilpnomelane (black) in chlorite.

All magnifications 60 diameters.

Face p. 174]

The Life History of the New Zealand Species of the Parasitic Genus Korthalsella.

By MISS G. B. STEVENSON, M.Sc.

[*Read before the Otago Institute, May 9, 1933; received by Editor, May 29, 1933; issued separately, September, 1934.*]

CONTENTS.

INTRODUCTION.

KORTHALSELLA is a genus of small parasitic plants including 15–20 known spp., which range from India and Malaya southwards and eastwards, to New Zealand and the Sandwich Islands. There are three New Zealand species—*Korthalsella Lindsayi* Engl., *K. salicornioides* Van Tiegh., and *K. clavata* Cheesem. The first mention of any of these plants comes in Hooker's "Flora Novae Zelandiae," where *Korthalsella salicornioides* is described under the name *Viscum salicornioides* Hook. Hooker had seen only plants without flowers or fruits, and his description is of the vegetative parts only, though he includes a shrewd guess that the "flowers will probably be found to be very small and to be sunk in the tips of the joints: the perianth to be of four valvate petals with a cellular, porous, amorphous anther adnate to the face of each petal, the pollen lodged in the cells of the anther" (Hooker, 1853).

At this time the plant was known only from the Bay of Islands in the North Island. It was perhaps its rarity and evident peculiarity that led Hooker to indulge in such a detailed forecast. In the "Handbook of the New Zealand Flora" brought out by him eleven years later, *K. salicornioides* and *Lindsayi* are both listed as *Viscum* spp. (Hooker, 1864, p. 108). This time, with actual material to hand, Hooker was not nearly so detailed in his descriptions of the flowers. For *Viscum Lindsayi* he states: "Flowers very minute, whorled on the joints of the peduncle, perianth three lobed, lobes persistent," and for *Viscum salicornioides*: "Flowers very minute, solitary or few together in the tips of the upper joints: perianth

three lobed, lobes persistent." *Korthalsella clavata* was first discovered in 1876 by Kirk and Enys in the Castle Hill Basin, Canterbury, on *Coprosma propinqua.* The plant was neither in flower nor in fruit. In 1891, they found it again in the same district in another locality on *Aristotelia fruticosa,* this time in fruit. Kirk published a description of it in the Trans N.Z. Inst., 1892. In the first edition of Cheeseman's "Flora of New Zealand" the three species are listed under the generic name *Viscum* (1906, p. 261): A note in the Appendix (p. 1151) refers to Van Tieghem's Memoirs on the Loranthaceae, in which are recognised many more genera for the family than are accepted in Engler and Prantl's "Pflanzenfamilien." Unfortunately, I have not had access to Van Tieghem's Memoirs, and do not know the grounds on which he separated out the genus *Korthalsella.* In the second edition of Cheeseman's Manual (1925) Van Tieghem's generic name is adopted, though no reason is given for making this change, and we have *Korthalsella salicornioides*, *K. Lindsayi*, and *K. clavata* established.

Cheeseman follows Kirk and ranks *K. clavata* as a separate species, but includes the reservation that he personally suspects that it is merely a variety of *K. Lindsayi.* Miss L. M. Cranwell, M.A., botanist to the Auckland Museum, was kind enough to send the writer all Cheeseman's herbarium material and also some collected recently by herself at Castle Hill. This has been carefully examined, and the conclusion drawn that *K. clavata* is a distinct species intermediate in most respects between the other two.

The work on which this thesis is based was carried out in the Botany Laboratory of the University of Otago, Dunedin. The author wishes to express her thanks to Dr J. E. Holloway for his help and encouragement throughout.

Material and Methods.

Korthalsella Lindsayi and *salicornioides* are regarded as fairly rare plants. "Although they occur throughout the whole length of the North and South Islands of New Zealand, they are everywhere local and rarely occur in any great quantity." (Cheeseman, 1910, p. 182.) Much of the hills around Dunedin, where the present investigation was carried out, is covered with *Leptospermum ericoides* scrub, but *K. salicornioides* occurs on the *Leptospermum* in only a few definite localities: it seldom occurs on anything but *Leptospermum*, though it has been reported also on *Gaultheria* and *Dracophyllum*. Similarly, *K. Lindsayi,* which occurs on a greater variety of shrubs—Cheeseman (1925) lists: *Sophora, Melicope, Metrosideros, Myrtus, Coprosma, Myrsine,* etc.—is found near Dunedin in the upper Botanical Gardens, on *Helichrysum glomeratum* and *Melicope simplex*, and also at one or two other localities on similar scrub. The infection in most of these places is dense, and there is no lack of material.

K. clavata is known only from Castle Hill Basin, where it is found on *Aristotelia fruticosa, Discaria,* and *Coprosma.*

Fresh material of *K. Lindsayi* and *K. salicornioides* was collected, and killed and fixed on the spot. Inflorescences for the various stages of floral and fruit development were fixed in Carnoy's Fluid, using 95% instead of absolute alcohol. Chromacetic was used also for a few collections, but was found to be not so good as the Carnoy. Seedlings, stems, and haustoria were fixed in formalin alcohol. The material was imbedded in paraffin and cut at 6, 8, and 10 μ. Double staining with safranin-gentian violet, and safranin-light green, and triple staining with safranin-gentian violet and orange G, were all brilliant after these killing and fixing reagents. Some of the later stages of fruits, with mucilaginous tissue, were difficult to infiltrate. The hard twiggy host stems with haustoria were found not to cut successfully after imbedding in paraffin. These were soaked in glycerin for two to three weeks to soften, and then cut in pith with a sliding microtome. This procedure gave very satisfactory results. Hand-cut sections were used for various micro-chemical tests.

Flowering material was collected from the end of August onwards. By the beginning of November it was found that the young fruits were forming. Seeds and seedlings were collected from January to April.

All drawings other than those showing general habit were made with the aid of either an Abbé camera lucida or a Zeiss reflex drawing apparatus. In the case of the habit drawings dividers were used for accurate measurements.

GENERAL MORPHOLOGICAL CHARACTERS.

Korthalsella Lindsayi: Figs. 1 and 4 show the habit of the plant. It is small, branched, succulent, and perfectly glabrous, jointed at the node, which is restricted, while the internode is flattened and broadly obovate. The outer part of the internode is continued up into a collar round the node. The growing apex is protected by these collars, which fold over it in just the same way as would young leaves, but each collar is a ring of tissue, not a whorl of separate emergences. At the node inside the collar, branches and inflorescences arise, usually 2 from one node, but sometimes 3 or 4. There is a thick cuticle, and most of the epidermal cells are strongly lenticular on the outer walls, especially in the young parts. Only the very youngest parts of the plant look green. The older branches and even the inflorescences look brown. Sections of the tissue show that in the photosynthetic layer, which lies under the epidermis of all parts of the plant, are groups of cells filled with a yellowish brown substance. Hand-cut sections of fresh material were treated with $FeCl_3$, and also some with $FeSo_4$, to see if these cells contained tannins. There was no colouration. With osmic acid this substance did not blacken. It is probably then resinous. Some sections were soaked in alkannin tincture for three days, but there was no detectable reaction either: this may have been due to the rather unsatisfactory nature of this stain, or to the resinous cells being already too coloured to show any change. Fig. 13 is a diagram of a transverse section of an internode, showing the position of these groups of resin cells.

As observed at Dunedin, *K. Lindsayi* infects *Helichrysum glomeratum* and *Melicope simplex* very densely. For example, on one branch of *Helichrysum glomeratum* there were 184 separate *K. Lindsayi* plants and also 5 plants on the *K. Lindsayi* itself. The obovate internodes of the *Korthalsella* are much the same shape as the small leaves of the two host plants mentioned, and this fact, combined with its more or less brown colour, makes it very inconspicuous unless carefully looked for.

The flowers are borne on definite inflorescences which are terminal, or arise as lateral branches from the nodes (Fig. 5). The flowers, which are green or brownish, are arranged in a definite way. At each node of an inflorescence there are 2 groups of flowers separated by 2 tufts of hair. Each group consists of one male flower, which stands out well above the collar, and four female flowers in a row below it, with only their tips projecting above the collar (Figs. 9 and 10). These groups are arranged regularly one above the other at successive nodes, up and down the inflorescence Fig. 11 represents a longitudinal section cut in the plane of the rows of male flowers. In some instances a decussate arrangement has been noticed: at one node the groups will alternate, as in Fig. 9 at the tip. This variation occurs fairly frequently. In one inflorescence it was found that at one node both the groups were doubled, consisting of 2 male flowers and 6 or possibly 8 female flowers per group. This was quite exceptional.

The vascular system consists of two separate main collateral bundles in the internodes, more or less fusing in the constricted node (Fig. 13). The separate bundles traversing the internodes give off nervures which supply the photosynthetic layer just under the epidermis. All the elements in the bundle have very small lumina. The tracheids are short, and are intermixed with the xylem parenchyma. This structure explains the brittle nature of the plant, which is very easily broken across. Vessels are not so common as very short tracheids, and are very narrow and mostly quite short also. The writer has not been able to distinguish any typical sieve tubes, and doubts if there are any. It seems that their place is taken by parenchyma—elongated cells, with rich cytoplasmic contents and conspicuous nuclei. In the older parts, at the base of the plant, the bundles are united to form a loose vascular cylinder—Fig. 36 Fig 35 represents a single bundle in transverse section.

Stone cells occur at any point in the plant and are to be seen in many of the figures. Crystal-containing cells occur commonly in the outer part of the flowers. These crystals are insoluble in dilute acetic, but dissolve in dilute nitric acid without the evolution of gas bubbles, and so were shown to be probably Calcium oxalate. These are common features of the Loranthaceae. (Solereder, 1908.)

K. salicornioides is a small tufted plant with slender terete branches, branched to a greater extent than *K. Lindsayi.* Fig. 2 is a habit drawing of *K. salicornioides* parasitic on *Leptospermum ericoides.* The stems appear jointed, being slightly constricted at each node. The outer photosynthetic and succulent part of the stem

is continued as a collar, which ensheathes the actual node and the lower end of the next succeeding internode. This structure is exactly analogous with that in *Salicornia,* where it has been suggested that the outer succulent part of the stem really represents the modified leaves from the node below, the collar then representing the fused and modified tips of these leaves. The ensheathing collars, just behind the apex, where the internodes have not yet elongated, fold over, and protect the growing point just as in *K. Lindsayi*: this has the same effect as a series of imbricating leaf primordia.

The vascular system is almost identical with that in *K. Lindsayi.* The internodes are traversed by two main bundles which give off strands into the photosynthetic tissue. Fig. 14 is a diagram of a transverse section of an internode. At the node, the bundles give off branch strands to the flowers or fruits and the lateral branches. In the oldest regions of the stems at the base of a plant there is, as in *K. Lindsayi,* a loose vascular cylinder. It is noticeable that all the vascular elements are narrow.

Infection of the *Leptospermum* by this species is sometimes very dense, and in some cases a host branch is clearly affected detrimentally by the infection. Such a branch may be seen to bear dead-looking, leafless twigs. In one instance 88 distinct plants of the parasite were counted on a single branch of *Leptospermum.*

Stone cells and crystals of Calcium oxalate occur throughout the plant as in *K. Lindsayi.* The epidermal cells also protrude strongly and have a thick cuticle. Cells completely filled with a bright orange-brown, supposedly resinous, substance occur dotted in the photosynthetic layer (Fig. 14). The same micro-chemical tests were applied to these as were carried out for *K. Lindsayi* with the same results.

Unlike *K. Lindsayi* there are no definite inflorescences, the flowers being borne at the nodes towards the tips of the ordinary branches. Here, also, they occur in the same definite group formation of one male flower and four female together, there being two groups to each node. The arrangement of the groups at the successive nodes is alternate and opposite—a decussate arrangement—in contrast to the regular vertical rows in *K. Lindsayi.* Fig. 8 is a habit drawing of the tip of a branch bearing flowers, and Fig. 12 a diagrammatic drawing of a longitudinal section of the same. Whereas there were irregularities in the arrangement of floral groups observed in *K. Lindsayi*—an alternate arrangement occurring in places—in *K salicornioides* no irregularities were found. As a large number of different inflorescences have been examined, it seems safe to conclude that probably the *salicornioides* arrangement is the more normal, and represents the type from which the *K. Lindsayi* arrangement has arisen.

In the Manual of the New Zealand Flora (Cheeseman, 1925) the floral descriptions for the species of *Korthalsella* are very imperfect. This no doubt is due to the fact that those descriptions are based on material representing a late stage of development in which fruit formation was well advanced. At the time the female flowers are fully developed only their perianth tips are above the

collar. They are, indeed, exceedingly minute for fully developed flowers, but sections show the embryo sacs to be ready for fertilisation. The male flowers are considerably larger and stand out well above the collar over the top of the female flowers (Figs. 8–12). Cheeseman (1925) states that the male flowers are much smaller than the female flowers, indicating that fruit formation was well advanced in the particular shoots he examined. He failed to notice the regular arrangement of the flowers: as the fruits grow larger and project above the collar, the arrangement becomes obscured, especially as all the flowers may not develop, or some may be injured or knocked off at some intermediate stage, so that gradually the definite numbers and the regular arrangement is lost. In *K. salicornioides* the male flowers persist for a surprisingly long time; they are usually to be found squeezed in between the fruits, which are clustered round the node In *K. Lindsayi* they drop off early after shedding their pollen.

Korthalsella clavata is shown in Fig. 7. It has the general appearance of *K. Lindsayi*, but the internodes are more attenuated. The most definite distinction is that the flowers are borne in whorls at the upper nodes and not on definite inflorescences as in *K. Lindsayi*, though the upper internodes between the topmost whorls of flowers become quite small and terete, as they are in the *K. Lindsayi* A comparison of Fig. 5 and Fig. 7 brings out this distinction. This feature, as well as the more slender nature of its vegetative parts, determines *K. clavata* to be quite distinct from *K. Lindsayi*, and worthy of a distinction of a separate species. On the whole, it is intermediate in character between the other two New Zealand species. The habit is like *K. Lindsayi*, but more slender, while the flowers are borne as they are in *K. salicornioides*. All the material that the author has seen was in a well-advanced fruiting stage, and no flowers could be found. Thus it was impossible to determine whether or not the arrangement of floral groups is decussate or in vertical rows.

Development of the Flowers.

The flowers, which are morphologically practically identical in the two species, *K. Lindsayi* and *K. salicornioides*, grow out as a whorl of undifferentiated ovoid cell masses in the axils of the collars behind the growing tip

The female flower (Fig. 15a) is quite globular, three or, quite rarely, four pegs of perianth lobes appearing at its tip as the flower nears maturity with the sessile stigma between them. One or more embryo sacs appear in the centre of the solid mass of the flower Fig. 20 is a drawing of a median longitudinal section of a mature female flower of *K. salicornioides*. The embryo sac is not cut medianly. It is seen that the flower is extremely small. It is quite sessile. There is no differentiation whatever into the typical floral organs. The sessile stigma is merely a receptive spot on the tip of the flower; its cells are secretory and the stigma is sticky, pollen grains becoming stuck to it. The perianth pegs are the minute protuberances from the tip of the flower encircling the stigma.

Vascular strands, consisting of one row of tracheal elements, run up the side of the flower out into each lobe. In the mature female flower there is a suggestion of different cell layers. The cells outside the vascular strands are fairly large. Those round the embryo sacs are fairly compact, except for those which directly abut on them, and which are becoming used up as the embryo sac grows. In later stages of fruit formation there is a more marked differentiation into layers. In the phylogenetic development of the flower each of these layers has probably been derived from a different floral organ. The position of the embryo sac with reference to the perianth lobes is inferior. The outer cell layer of the flower probably represents the fused bases of the petals, the three perianth lobes representing the free tips of these, not the complete reduced petals. Inferior ovaries occur in many different families of plants, but all are not morphologically identical Johnson (1889) and Thoday and Johnson (1932) have discussed reduction of the female flower for two species of *Arceuthobium*, Treub (1882) for two species of *Loranthus* and one of *Viscum*, and Van Tieghem (1869) for *Viscum album.* From these it is clear that the *Viscum* female flower is more reduced than that of *Loranthus* Treub brought forward evidence in favour of the derivation of the former type from the latter. The floral type in *Korthalsella* seems to the present writer to be even more reduced than that of *Viscum*

In *Korthalsella* one or more spore mother cells develop in the central dome-shaped mass of compact tissue, and a tetrad division takes place in each Linear tetrads can be seen, in which either the uppermost or the lowermost cell is developing into an embryo sac. Fig. 23 shows a linear tetrad Embryo sac formation appears to be quite normal Several embryo sacs may reach an advanced state in each flower. The number found varied from one to five. There is no sign of any definite arrangement of these, as has been noted in *Viscum album* (Treub, 1882). They may lie side by side in a group or separated by parenchyma At exactly what stage a single embryo sac becomes dominant is hard to say. In the youngest stages of fertilised embryo sacs only one is left, the others having degenerated. The cytoplasm in the mature embryo sac is richly stocked with highly refractive globules. Although the flower is so reduced that the organisation of even the ovule is lost, there is, so far as these investigations show, no reduction in the embryo sac.

The male flower is perhaps the most peculiar feature of the plant. Figs. 15b, 8, 9, and 10 show the outward appearance with three perianth lobes—much bigger than the mere pegs on the female flower —folded over a rounded head in the centre of which is a pore, through which pollen (poll.) is being shed; the pollen grains adhere in a mass. Cheeseman (1925) states that the male flower has sessile anthers adhering to the perianth lobes. This is quite incorrect; he probably thought that the flower was the same as in *Viscum album*, but this is not the case. Fig 30 shows a median longitudinal section of an unopened male flower of *K. Lindsayi.* Fig. 27 is a drawing of a slightly oblique transverse section of an open male

flower of *K. salicornioides*, and Fig. 29 shows a longitudinal section of an open male flower of *K. salicornioides.* The complete male flower has only one pollen sac, which is divided by septa into six pollen chambers. This whole structure is annular in shape and arises from the base of a short perianth tube. The central opening is a very minute pore, so that the outward appearance of this annular structure is hemispherical. The pore leads down to the central part of the flower or receptacle, which is separate from the sac, though it abuts closely on it. The wall of the pollen sac consists of an outer epidermis, a subepidermal fibrous layer, and one inner layer of cells: this wall is continuous from the circular outside margin at the base of the petals, over the top, down the neck of the central pore, and forms the bottom wall of the sac; the fibrous layer is not differentiated in the bottom wall, but seems to extend for a longer or shorter distance down the neck (Figs. 27 and 30). There is a separate tapetum round each of the six pollen masses as Fig. 28, which represents a tangential longitudinal section, clearly shows. In an open flower both the tapetum and the inner layer of cells have been used up, and also the epidermis outside the fibrous layer has disappeared, so that the wall of the pollen sac at this stage consists solely of the fibrous layer. The septa break and the pollen chambers become continuous. The circular wall round the pore below the end of the fibrous layer become ruptured, and an opening is thus made from the pollen chambers through the pore to the outside. The pollen exudes in this manner from the pore (Figs. 9 and 10). No stages were observed in the present study younger than that shown in Fig. 30. Possibly the manner in which the ring-shaped pollen sac actually originates would afford an indication as to how it is to be interpreted. In the light of what is found in the other members of the family, it would seem possible that it represents fused sessile anthers adnate to the fused petal bases. In Fig. 27 a bending in of the fibrous layer at the septa between the pollen chambers in two places may indicate the boundaries of fused sessile anther lobes.

The condition of the male flower in other *Korthalsella* spp. should help towards an interpretation of this structure in *K. Lindsayi* and *K. salicornioides.* I have not had access to Van Tieghem's Memoirs on the Loranthaceae and do not know if an account of any of these other species is given.

Development of the Fruit.

The fertilised egg is scarcely distinguishable from the endosperm cells which completely fill the embryo sac from a very early stage (Fig. 21). The embryo is an undifferentiated cell mass which grows very slowly at first, all cells resulting from divisions of the fertilised ovum going to form the embryo which soon becomes separated from the sac membrane by a layer of endosperm cells (Fig. 26). The endosperm divides fairly rapidly and enlarges at the expense of the surrounding cells. At the same time the cells of the fruit wall show a differentiation into layers. In the middle layer, from the

tip of the fruit to the depth of the endosperm, but not beneath it, the cells become first meristemmatic (Fig. 21), then elongate radially (Fig. 26). As the embryo and endosperm grow, these cells become differentiated as the mucilaginous elements, the individual cells becoming greatly enlongated. Their nuclei also become attenuated and stain with sanfranin as red streaks. The cell contents disappear, and the walls finally become mucilaginous, the whole mass staining very densely (Fig. 31). The embryo lies at the top (anterior) end of the endosperm and when the fruit is ripe protrudes from it (Fig. 32). The embryo cells are small, with large nuclei and dense cytoplasm, the endosperm cells densely stocked with starch granules. The embryo is surmounted by a cap of parenchymatous tissue. When the seed is shed, it consists of endosperm, embryo, and the few cells of the cap, the whole surmounted by the viscid tissue. It is an unprotected structure, lacking a true seed coat. It is very small and quite unadapted to bird attraction.

Many fruits fall off complete, the embryo, endosperm, and adherent mucilaginous cells becoming more or less shot out of the fruit coat through the broken end of the latter. In some fruits the tip is ruptured and the seed forced out through the top, no doubt by the swelling of the mucilaginous tissue. A certain internal pressure is indicated by the flattening of the innermost cells of the fruit wall (w in Fig. 32), but the fruit is so small that this is not very great. In all cases the fruit or the seed falls near at hand, many adhering to the parent plant itself. This highly inefficient seed distribution renders the plant incapable of spreading itself over any distance. The seeds are produced in large numbers in proportion to the size of the plant, and these are brought to maturity between November and February. Each contains a considerable amount of stored food in the form of starch granules (Fig. 32), more than it would seem possible for the plant, with its restricted photosynthetic apparatus, to manufacture in the time. It is highly probable that the source of this supply is the host, from which carbohydrates as well as water and salts are taken. The path of this translocation is most likely through the xylem, where there is a large connection between haustorium and host, and not through the phloem, in which it is very doubtful if there is any connection with the parasite.

GERMINATION AND HAUSTORIAL ACTIVITY.

The embryo is already protruding slightly from the endosperm when the seed is shed (Fig. 32). It immediately grows out to form a radicle which closely applies itself to the surface of the host. The radicle seems to digest its way through the outer layers of the host and grows into the vascular tissue, with which it at once forms connections. As the young seedling develops, a growing point becomes differentiated under a cotyledonary collar, which remains for a time embedded in the endosperm from which it absorbs the stored food (Fig. 19). In *K. Lindsayi* the seed usually sends out a short radicle which immediately applies itself to the substratum.

In *K. salicornioides* the radicles observed were longer and seemed to straggle along the stem until they grew into a niche in the bark (Figs. 17 and 18.) Many seeds fall on to leaves of the host plant, and when these are shed the seeds are lost. Commonly in *K. Lindsayi* they become lodged in the angles of the host stems. Seedlings of this species were found to occur much more plentifully than those of *K. salicornioides*: the former were also found not infrequently on the parent plant (Figs. 3 and 4), though this occurrence is as much a result of the inefficient seed distribution as of the dense growth. Fig. 18 shows a *K. salicornioides* seedling on the parent plant. When the *K. Lindsayi* seeds become lodged in the angles of the branches of the parent plant they germinate readily. The young seedlings are readily distinguishable from the substratum by their light green colour, small size, and attenuated hypocotyl and radicle region, but at a somewhat later stage they are no longer distinguishable from an ordinary branch. No doubt if a careful investigation of many plants were made and sections cut of the branching it would be found that many *K. Lindsayi* plants are compound, consisting of two or more, parasitic the one upon the other. When, on the other hand, the seed becomes attached to a flat internode its character as a plant parasitic on its parent does not become obscured with age (Figs 3 and 4). In *K. salicornioides*, the seeds were found to be not so commonly in the angles of the *Leptospermum* stems as along the twigs, where they stuck readily to the rough bark. The number of seedlings of this species found later was not in proportion to the number of seeds that had stuck and begun their germination The rough bark is continually flaking off, so that, besides those seeds which drop off or are knocked off, a number will be shed with the bark before the radicle of the seedling has grown down into the host stele. Notwithstanding, on some branches of *Leptospermum* the *K. salicornioides* was seen to be exceedingly plentiful

The young haustorium penetrates the host and spreads out in a club-shaped head Fig. 37 shows a longitudinal section of a *K. Lindsayi* stem just above a node with a young haustorium penetrating; the haustorial head is indicated by stippled cell contents. The head of the haustorium enlarges by digesting the tissue immediately in front of it. Very soon bands of haustorial tissue begin to grow along the line of the cambium, both up and down the stem, and round the side of the stele. Fig. 36 is a transverse section of a *K. Lindsayi* stem just above a node showing a seedling haustorium. The haustorium has sent arms round the cambial line of the loose vascular cylinder. Tracheidal cells in the haustorium directly abut on the tracheidal elements of the stem stele. The cells of the haustorium along its margin are large, with large brilliantly-staining nuclei These cells appear to be actively digesting the tissues in front of them. The extent of the haustorium in Fig. 36 is indicated by showing the cell nuclei. Fig. 38 is a drawing of a very young haustorium of a *K. Lindsayi* seedling on a *K. Lindsayi* internode, the latter being cut transversely. Haustorial cells all were thin-walled and had large nuclei, much larger than

those in the large-celled part of the host stem, though not a great deal larger than those of the photosynthetic layer. The haustorium is tapping the elements (C.V. and S.V.), which are crushed by its growth and have been separated from their fibre (f) by a considerable amount of secondary growth of the haustorium (2°). The haustorium entered the bundle from the side at the cambium layer. It digested the cambium and soft tissues of this bundle, and has since enlarged considerably in its place. A comparison of this figure with Fig. 35 of a single bundle will make this point clearer. The isolated vascular elements, S.V., probably belong also to the xylem of the original bundle and have been surrounded by haustorial tissue. Fig. 33 shows a transverse section of a *Leptospermum* twig with an older haustorium of *K. salicornioides.* The haustorial tissues are drawn in detail; the tissues of the host twig are indicated by cross hatchings. The section is taken where the *Leptospermum* twig is giving off a branch trace, so that there is a certain irregularity as seen, for example, in the contour of the pith. The haustorium penetrated along the line of the cambium, which, as well as the phloem, it has completely eliminated. No phloem was to be seen at any point on this section between the outer margin of the haustorium and the periderm. The haustorial cells became meristemmatic, and a considerable amount of mixed parenchyma and short tracheidal cells has been formed. These are all linked up with the vascular system in the *Korthalsella* stem. At the side of the host stem into which the haustorium first grew there is the greatest amount of haustorium developed. Towards the far side of the stele there is an increasing amount of wood. The cambium here was the last to be eliminated, and would continue to be formed until the haustorium grew right round. The difference in the amount of wood at the near and far sides, however, represents a longer time than is represented in the age of the parasite plant, so that a fair amount of digestion of actual woody elements has taken place. Again the margin of the haustorium consists of large papillose cells which appear to be both forcing themselves between the elements of the host and to be digesting them.

Fig. 34 shows in detail a portion of a band of haustorial cells in a very young haustorium of *K. salicornioides* on a *Leptospermum* twig. The cambium has been digested away, and also the very young wood and the young phloem. Tannin in a wood medullary ray and in a few inner bark cells is black. The thick line along the phloem margin of the haustorial cells was a deeply staining strip of material, doubtless indicating active digestion along that border. Cellulose tissues are drawn black; lignified tissues are cross-hatched. The nuclei in the haustorium were large and brilliantly staining. The ovoid bodies in the haustorial cells are probably chloroplasts. In one series of sections of a medium aged haustorium on a *Leptospermum* twig the vessels of the host were seen to be all occluded with resins or tannins along the advancing margin of the haustorium. The cells, which were being killed by the secretion of the parasite, were forming resistant masses in the tissues. Perhaps the mistletoe

killed the wood parenchyma and the wood rays faster than it could digest them. Their material broke down into these substances just as it happened in the case of cells killed by exposure in wounds or cells cast off in the bark.

Discussion.

Korthalsella salicornioides and *K. Lindsayi* are greatly reduced. This reduction is exhibited in the habit generally and in the very small size of all the parts; in the structure of the flowers in which there are none of the typical angiosperm floral organs; in the lack of leaves; in the general simplicity of organisation of the plant parts, and also in the completely undifferentiated embryo. The photosynthetic tissue is of small extent in proportion to the number of fruits matured, and is largely blocked by resins in the older stems. This must mean that the *Korthalsella* draws manufactured food from the host– that parasitism has proceeded to a further degree than in those leafy Loranths which need to draw only water and salts.

The great reduction in size of the fruit has led to restricted and localised occurrence of the plants, because all the seeds are shed very close to the parent plant, and many on to the parent plant itself. On *K. Lindsayi*, with its flattened internodes, this "cannibalism" occurs to a much greater extent than in *K. salicornioides*. This complete inability in both species on the part of the plant to distribute itself over any distance has resulted in its becoming confined to isolated districts. Where it does occur, however, it may be exceedingly plentiful. An indication of the slowness with which distribution takes place is seen in the frequent fact that some individual shrubs can be densely covered with one or other of the parasites, whilst others of the same kind within a few feet are quite uninfected.

This type of reduction to extreme minuteness of the whole plant and of its fruits has become definitely disadvantageous. It seems that these species of *Korthalsella* have passed the minimum of reduction and must be on the road to extinction. They are no longer able to distribute their seeds any distance or actively to invade new ground. Their distribution throughout the length of New Zealand, but everywhere rather rare and local, also points to their being dying species.

Korthalsella is not being eliminated by any competition. It is dying out of its own inefficiency. There is no competition between the host and the parasite, though there may be a certain amount of competition between several plants parasitic on the same branch. This competition cannot be a very strong factor in the survival of the *Korthalsella* when infection can continue up to the stage it does. Another factor that may influence its survival would come into operation if the extent of the infection prevented the further growth of the branch or absorbed so much of its food supply that it died. This probably does occur, but rarely, the writer never having seen an instance of a branch killed by *Korthalsella* on it, although many infected plants have been examined. This fact is of greater significance in

larger parasitic species which are more of a drain on their hosts. Competition between infected and uninfected plants does not occur; if uninfected plants are near enough to compete they become infected by contact with the plants they would be likely to oust. Where the *Leptospermum* scrub becomes invaded by other shrub species, as sometimes happens, a new factor in the elimination of the *Korthalsella* by the elimination of its host by non-susceptible species comes in.

These reduced characters of *Korthalsella salicornioides* and *K. Lindsayi* can scarcely be interpreted as adaptations to anything. It is sometimes considered that parasitism induces reduction. In most cases parasites are reduced or peculiar plants. It is argued that with a ready food supply the stimulus to form food-manufacturing organs, namely, leaves, is removed. But it is not easy to see how a plentiful food supply should influence the formation of flowers, so that gradually the organisation of these should become altered.

In the Loranthaceae there are many peculiar and highly specialised species which represent, as it were, the twigs of a branching family tree; the relationship between some is close; between others more distant. Several lines of descent can be traced, especially in floral morphology, yet in all these species the general habit is the same, and the type of environment similar also. In all families different lines of descent can be traced. Where the changes of structure cannot be explained in terms of adaptations to an environment it is said that there is a trend of development in a family, that it is a case of orthogenesis. There are many characters in plants, especially floral characters, which are totally inexplicable as adaptations and on which natural selection could not have been conceived to act, for example, the structure of the male or female flower in *Korthalsella*. Buchholz (1) has pointed out a case of selection which is often overlooked, and which is of wide occurrence in Angiosperms as well as in Gymnosperms. In *Korthalsella* there are several embryo sacs to each flower, but only one embryo to each fruit. A domination of one individual has occurred, perhaps we might say through a metabolic character which enabled it to grow quickest. Every individual has a whole complex of characters, many of which are directly linked. At most of the critical stages in the life history there is only one, or at most only a few, controlling factors. It is at the critical stages of the life history that selection occurs. Characters which thus influence but one stage, *e.g.*, rate of metabolism controlling growth of fertilised embryo sacs will be preserved, together with any characters to which they have become linked. It is thus conceivable how useless and even detrimental characters may become preserved through linkage to other characters. The evolution of the plant must occur at all stages of the life cycle. The survival and continuance of useless and detrimental characters in an orthogenetic trend in any line of descent, as the reduction of the flower in the Loranthaceae, is possibly to be explained by the continuance of a whole string of inter-related characters, of which enough are useful in the life history of the plant

to carry the others which are not useful or even disadvantageous. The balance between useful and detrimental characters is the margin on which the species progresses or retrogresses.

Summary.

1. The New Zealand species of *Korthalsella* were first put in the genus Viscum by Hooker. Cheeseman in his 2nd Edition of the New Zealand Flora moved them into Van Tieghem's genus *Korthalsella*.
2. There are three closely allied species. They are small tufted parasitic plants 2-4 inches high, leafless and glabrous, with jointed stems, terete in *K. salicornioides*, and with flattened internodes in *K. Lindsayi* and *K. clavata*. The flowers are minute, borne in groups of one male and four female flowers together, two groups forming a whorl at a node.
3. The female flowers are ovoid with three minute perianth pegs at the tip, a sessile stigma between. They consist of homogeneous tissue with 1-5 embryo sacs in a group at the centre. The male flower, also minute, has a single six-chambered pollen sac which is ring-shaped, and is considered to represent fused sessile anthers adnate to a short perianth tube. It is a highly peculiar structure.
4. All cells resulting from divisions of the fertilised egg form the embryo, which is an undifferentiated globular mass of cells; a viscous layer of radially elongated mucilaginous cells develops from the middle region of the fruit wall. When the fruit is ready to be shed the embryo has elongated and is protruding from the endosperm.
5. Dehiscence is variable, the seed slipping from the fruit to fall near at hand; seed distribution is ineffective.
6. Germination frequently takes place when the seed is shed on to the parent plant, resulting in a sort of cannibalism.
7. The genus *Korthalsella* is considered to be very reduced. The typical floral organs are not represented, the flowers being very simple and very minute. The small size of the fruits has resulted in inefficient seed distribution leading to localised occurrence of the plants. It seems that the New Zealand species of *Korthalsella* have passed the minimum of reduction and are on the road to extinction.

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DESCRIPTION OF PLATES

FIG. 1.—Habit drawing *Korthalsella Lindsayi* parasitic on *Helichrysum glomeratum*. Natural size.

FIG. 2.—Habit of young plant of *K. salicornioides* parasitic on *Leptospermum ericoides*. Natural size.

FIGS. 3 & 4.—Seedlings of *K. Lindsayi* on *K. Lindsayi*. Natural size; s.: seedling; note also germinating seeds.

FIG. 5.—Branch of *K. Lindsayi* with inflorescences in fruit. X 4.

FIG. 6.—*K. salicornioides* shoot in fruit. X 4.

FIG. 7.—Habit of *K. clavata*. Natural size.

FIG. 8.—*K. salicornioides* tip of shoot in flower; ♂: male flower; ♀: tip of female flower; poll.: exuding pollen. X 10.

FIGS. 9 & 10.—Inflorescences *K. Lindsayi*. X 10.

FIG. 11.—Diagram of a longitudinal section of a *K. salicornioides* shoot with flowers; ♂: male flower; ♀: female flower; col.: collar; node: node. X 5.

FIG. 12.—Diagram of a longitudinal section of a *K. Lindsayi* inflorescence. X 5.

FIG. 13.—Diagram of transverse section of *K. Lindsayi* internode; gr. res.: groups of resin cells; ph. t.: photosynthetic tissue; v. b.: vascular bundle; cort.: cortex; ep.: epidermis.

FIG. 14.—Diagram of a transverse section of a *K. salicornioides* internode.

FIG. 15.—*K. Lindsayi;* a: female flower; b: male flower. X 30.

FIG. 16.—Fruits (a) *K. salicornioides;* (b) *K. Lindsayi.* X 10.

FIG. 17.—Germinating seed of *K. salicornioides.* X 12.

FIG. 18.—*K. salicornioides* seedling on *K. salicornioides.* X 10.

FIG. 19.—Section of germinating seed of *K. Lindsayi;* end.: endosperm collapsed, the food store largely withdrawn from it; rad.: radicle of seedling; cot.: cotyledonary collar still embedded in endosperm; g.: growing apex. X 110.

FIG. 20.—Longit. median section female flower of *K. Salicornioides;* st.: stigma; per.: perianth. X 110.

FIG. 21.—Longit. median section *K. Lindsayi* developing fruit in young stage; z.: fertilised egg; end.: segments of endosperm as yet without cell walls; v.: cells which are going to form the viscous layer becoming meristemmatic; st.: stigma; per.: perianth lobes. X 110.

FIG. 22.—Young embryo sac *K. Lindsayi.* X 235.

FIG. 23.—Spore tetrad in *K. Lindsayi* female flower; note faint nuclei. X 235.

FIG. 24.—Embryo sac *K. salicornioides.* X 235.

FIG. 25.—Longit. median section *K. Lindsayi* female flower. X 110.

FIG. 26.—Longit. median section *K. Lindsayi* developing fruit; emb.: embryo; end.: endosperm; v.: developing viscous layer. X 110.

FIG. 27.—Transverse section male flower *K. salicornioides*, slightly oblique; per.: perianth; pol. gr.: pollen grain; sep.: remains of septa between pollen chambers; f.: fibrous layer; ep.: remains of epidermis seen in places. X 110.

Fig. 28.—Longit. tangential section unopened male flower *K. Lindsayi; per.*: perianth; pol. gr. pollen grain; tap.: tapetum; f.: fibrous layer. X 110.

Fig. 29.—Longit. median section male flower of *K. salicornioides;* per.: perianth; pol. gr.: pollen grain; pol. sac w.: pollen sac wall. X 110.

Fig. 30.—Longit. median section male flower *K. Lindsayi;* pore: central pore; pol. gr.: pollen grain; f.: fibrous layer; ep.: outer layer of pollen sac wall; i.: remains of inner layer of wall; per.: perianth lobe. X 110.

Fig. 31.—Longit. median section *K. salicornioides* developing fruit; emb.: embryo; end.: endosperm; v: viscous tissue; st.: stigma; per.: perianth lobe. X 110.

Fig. 32.—Longit. median section of mature fruit of *K. Lindsayi;* st.: stigma; per.: perianth lobe; v.: viscous tissue somewhat collapsed in preparation of section, emb.: embryo; end.: endosperm; cap.: parenchyma; cap; w. wall cells flattened by internal pressure. X 110.

Fig. 33.—Transverse section of *Leptospermum* twig with *K. salicornioides* haustorium surrounding stele of host; p.: pith of host stele; w. v.: wood vessels; w. f.. wood fibres; h.: haustorial tissue showing considerable secondary growth X 45

Fig. 34—Detail of young *K. salicornioides* haustorium in *Leptospermum.* X 425.

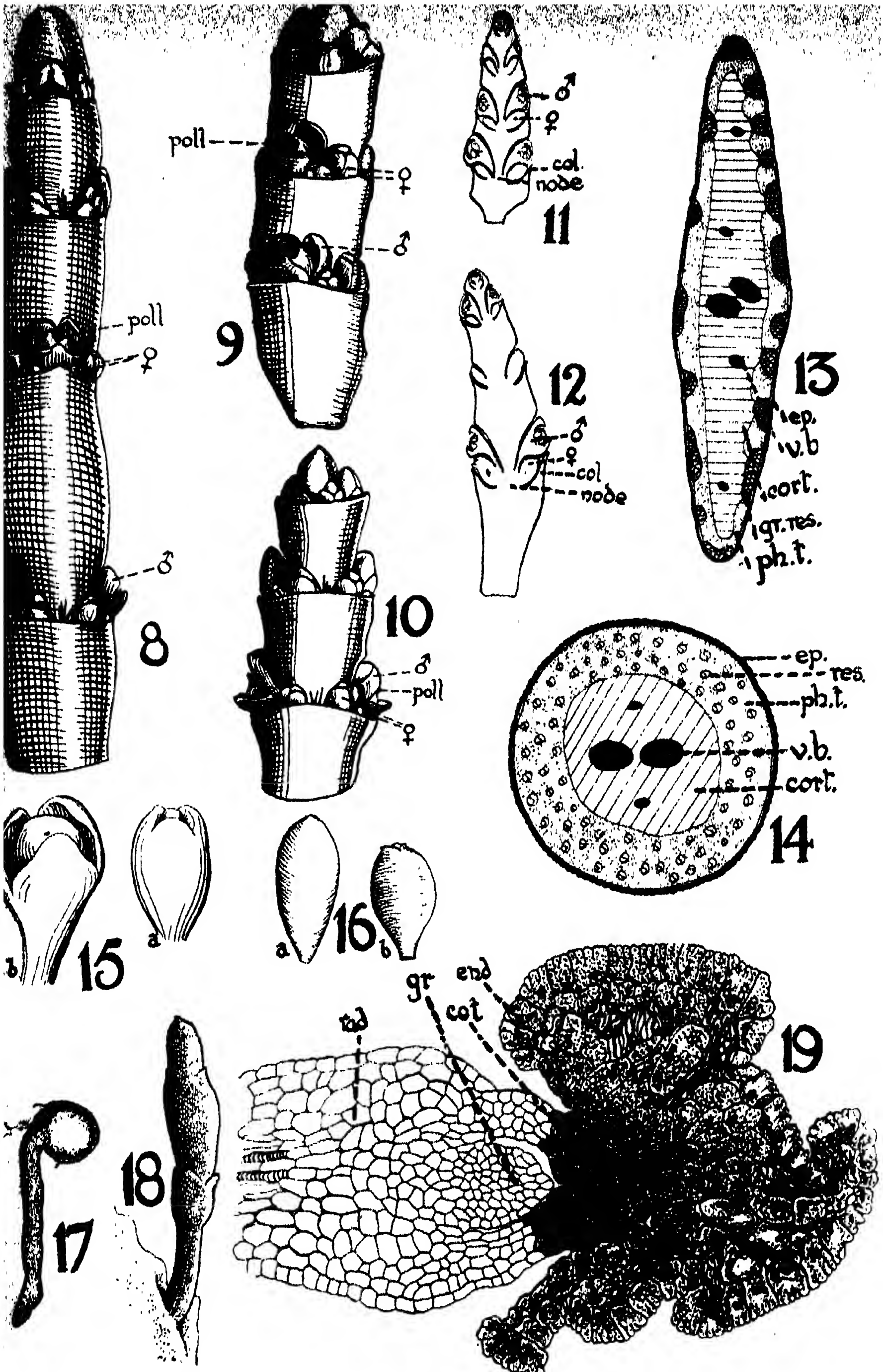
Fig. 35.—Transverse section of a vascular bundle in *K. Lindsayi* internode. Cellulose walls black, lignified walls cross-hatched. X 220.

Fig. 36.—Transverse section of *K. Lindsayi* stem immediately above a node showing a young haustorium; h.. partly surrounding stele of host stem (st.); lat. br.: lateral branch bud; 1st col., 2nd col.: two successive collars of the bud; col.: tip of collar of the lower node of host stem. X 50.

Fig. 37.—Longit section of *K Lindsayi* stem with a seedling *K. Lindsayi* haustorium. Cell contents are stippled in the haustorial cells. X 90.

Fig. 38.—Transverse section part of a *K. Lindsayi* internode showing the young haustorium of a *K. Lindsayi* seedling. Nuclei are drawn in the haustorial cells; e.v. and s.v.: vascular elements belonging to the host; f.: fibre of host separated from the vascular elements by secondary growth of the haustorium at the point marked 2°. X 90.

FIG 1.—Habit drawing *Korthalsella Lindsayi* parasitic on *Helichrysum glomeratum* Natural size FIG 2—Habit of young plant of *K salicornioides* parasitic on *Leptospermum ericoides* Natural size FIGS. 3 and 4.—Seedlings of *K Lindsayi* on *K Lindsayi*. Natural size. s seedling. Note also germinating seeds. FIG. 5—Branch of *K. Lindsayi* with inflorescences in fruit × 4. FIG 6—*K. salicornioides* shoot in fruit. × 4 FIG 7—Habit of *K clavata* Natural size



g. 8. -K. *salicornioides* tip of shoot in flower; ♂ : male flower; ♀ : tip of female flower; poll.: exuding pollen. × 10. Figs. 9 and 10.—Inflorescences *K. Lindsayi.* × 10. Fig. 11.—Diagram of a longitudinal section of a *K. salicornioides* shoot with flowers; ♂ : male flower; ♀ : female flower; col.: collar; node: node. × 5. Fig. 12.—Diagram of a longitudinal section of a *K. Lindsayi* inflorescence. × 5. Fig. 13.—Diagram of transverse section of *K. Lindsayi* internode; gr. res.: groups of resin cells; ph. t.: photosynthetic tissue; v. b: vascular bundle; cort.: cortex; ep.: epidermis. Fig. 14.—Diagram of a transverse section of a *K. salicornioides* internode. Fig. 15.—*K. Lindsayi*; a; female flower; b: male flower. × 30. Fig. 16.—Fruits (a) *K. salicornioides*; (b) *K. Lindsayi.* × 10. Fig. 17.—Germinating seed of *K. salicornioides.* × 12. Fig. 18.—*K. salicornioides* seedling on *K. salicornioides.* × 10. Fig. 19.—Section of germinating seed of *K. Lindsayi*; end.: endosperm collapsed, the food store largely withdrawn from it; rad.: radicle of seedling; cot.: cotyledonary collar still embedded in endosperm; g.: growing apex. × 110.

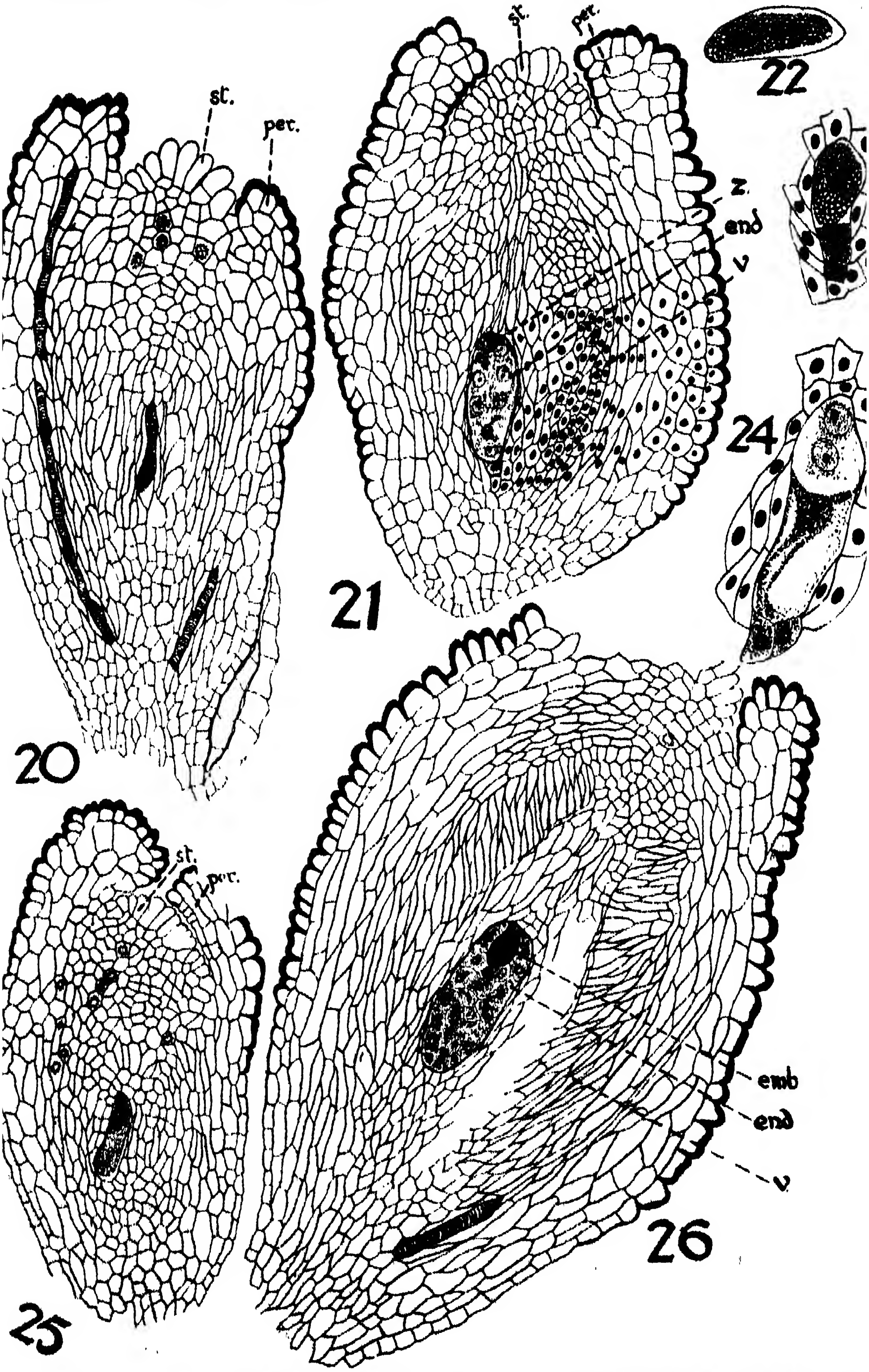


FIG. 20.—Longit. median section female flower of *K. salicornioides*; st.: stigma; per.: perianth. × 110. FIG. 21.—Longit. median section *K. Lindsayi* developing fruit in young stage; z.: fertilised egg; end.: segments of endosperm as yet without cell walls; v.: cells which are going to form the viscous layer becoming meristemmatic; st.: stigma; per.: perianth lobes. × 110. FIG. 22.—Young embryo sac *K. Lindsayi*. × 285. FIG. 23.—Spore tetrad in *K. Lindsayi* female flower: note faint nuclei. × 285. FIG. 24.—Embryo sac *K. salicornioides*. × 235. FIG. 25.—Longit. median section *K. Lindsayi* female flower. × 110. FIG. 26.—Longit. median section *K. Lindsayi* developing fruit; emb.: embryo; end.: endosperm; v.: developing viscous layer. × 110.

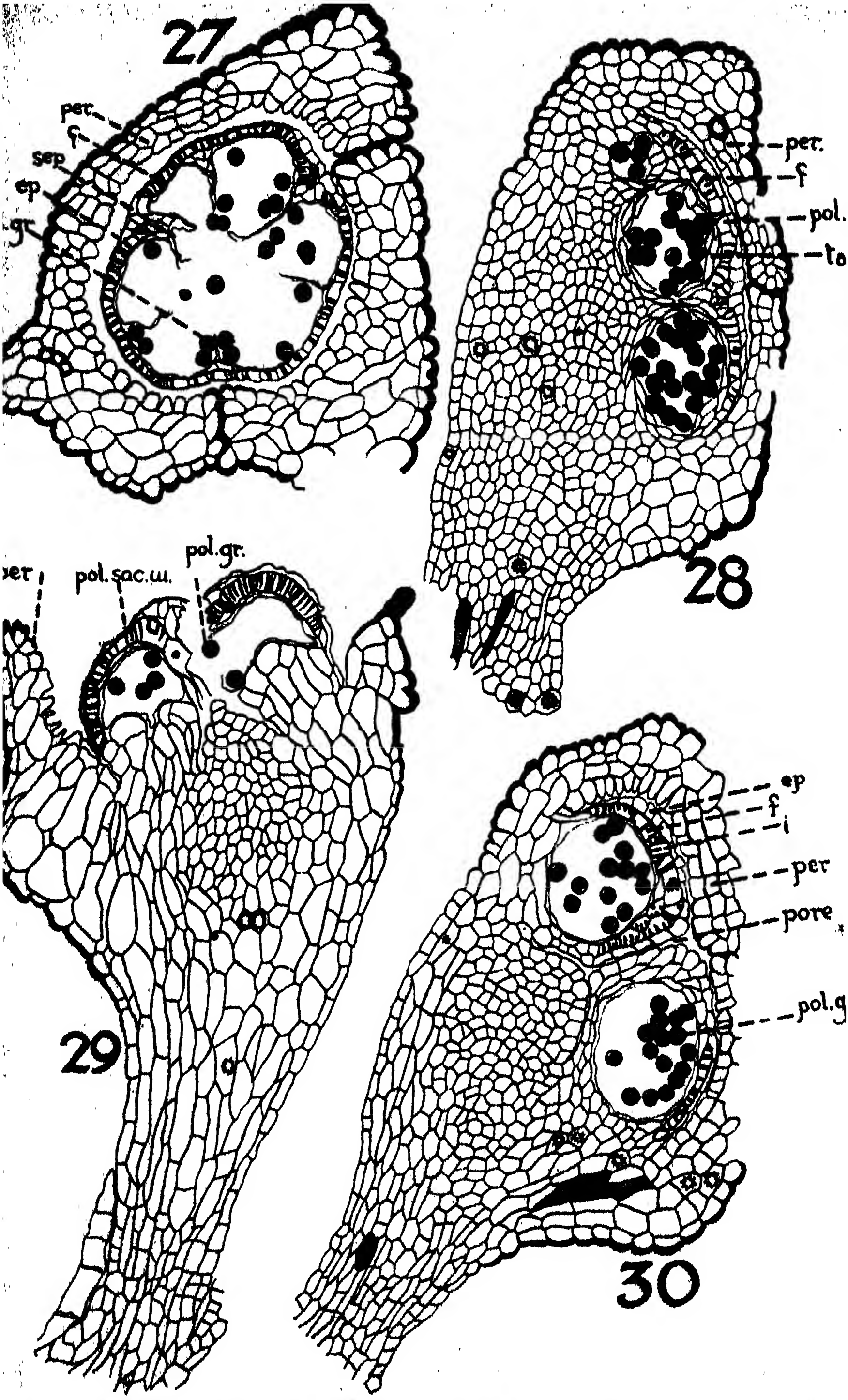
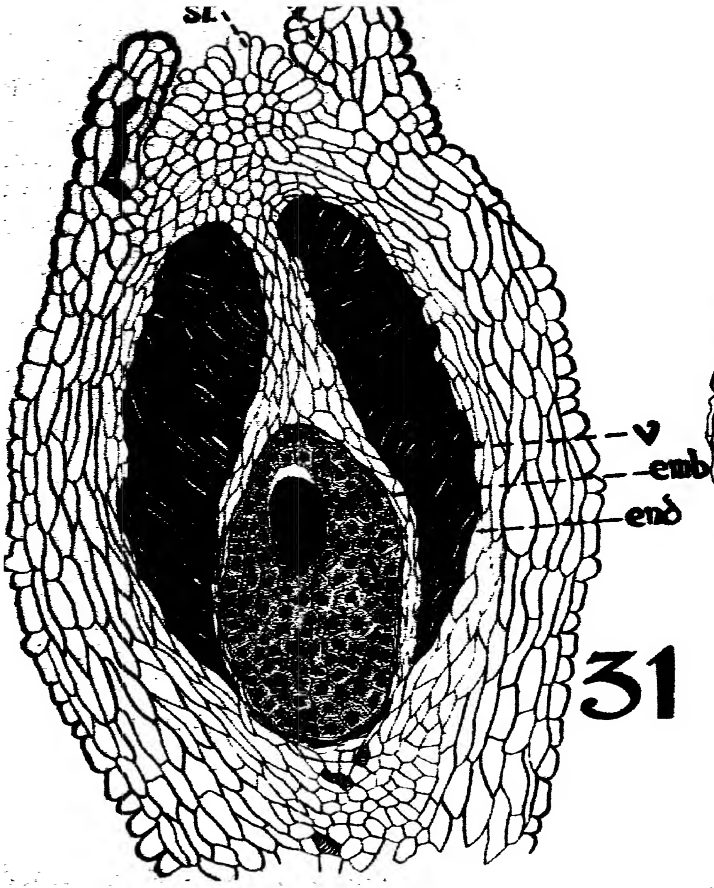


FIG. 27.—Transverse section male flower *K. salicornioides*, slightly oblique; per.: perianth; pol. gr.: pollen grain; sep.: remains of septa between pollen chambers; f.: fibrous layer; ep.: remains of epidermis seen in places. × 110. FIG. 28.—ongit. tangential section unopened male flower *K. Lindsayi;* per.: perianth; gr.: pollen grain; tap.: tapetum; f.: fibrous layer. × 110. FIG. 29.— median section male flower of *K. salicornioides;* per.: perianth; pol. gr.: grain; pol. sac w.: pollen sac wall. × 110. FIG. 30.—Longit. median male flower *K. Lindsayi;* pore: central pore; pol. gr.: pollen grain; us layer; ep.: outer layer of pollen sac wall; i.: remains of inner layer per.: perianth lobe. × 110.



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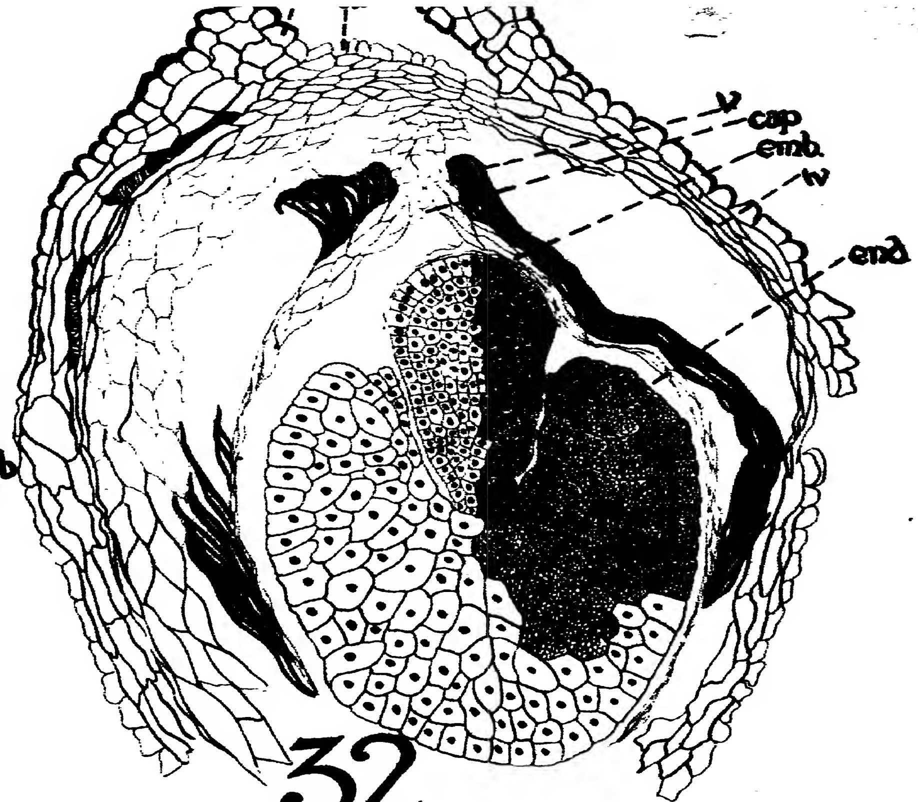

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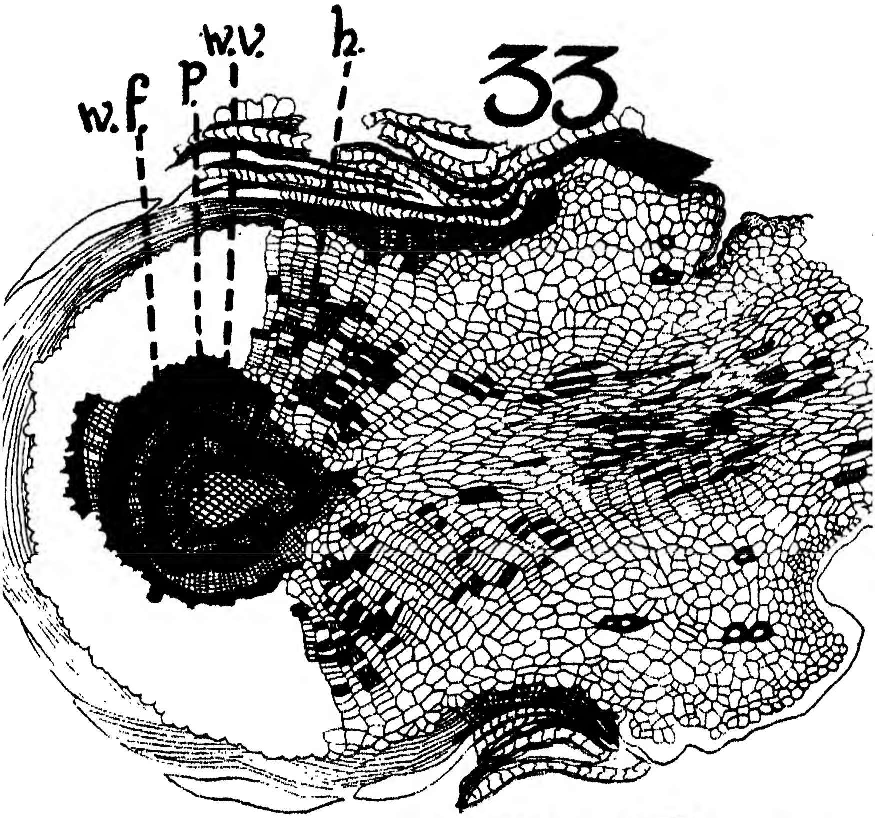


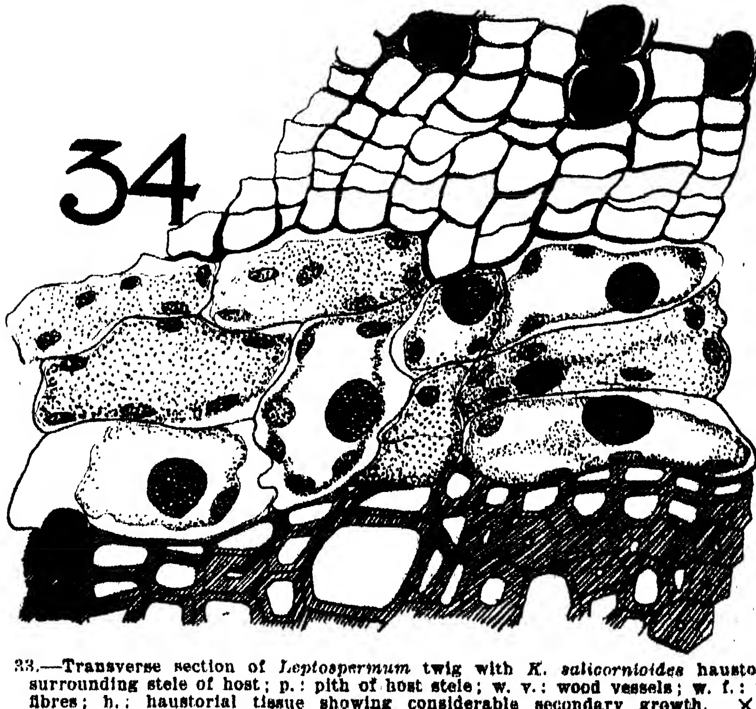


FIG. 33.—Transverse section of *Leptospermum* twig with *K. salicornioides* haustorium surrounding stele of host; p.: pith of host stele; w. v.: wood vessels; w. f.: wood fibres; h.: haustorial tissue showing considerable secondary growth. × 45.
FIG. 34.—Detail of young *K. salicornioides* haustorium in *Leptospermum*. × 425.

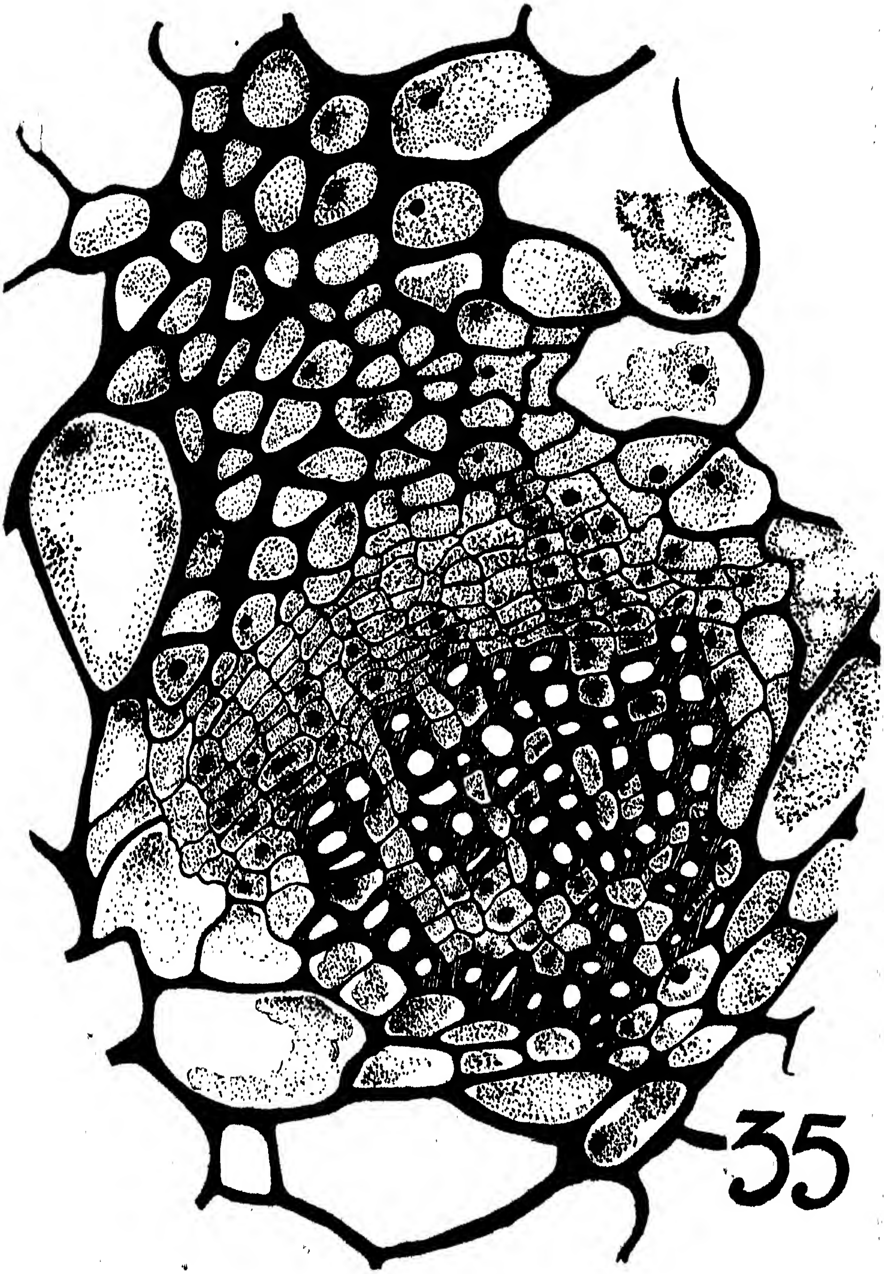
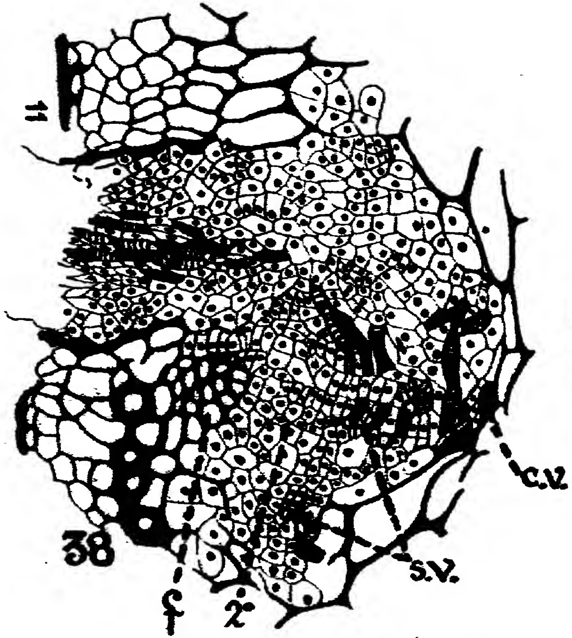


FIG. 35.—Transverse section of a vascular bundle in *K. Lindsayi* internode. Celluloso walls black; lignified walls cross-hatched. × 220.



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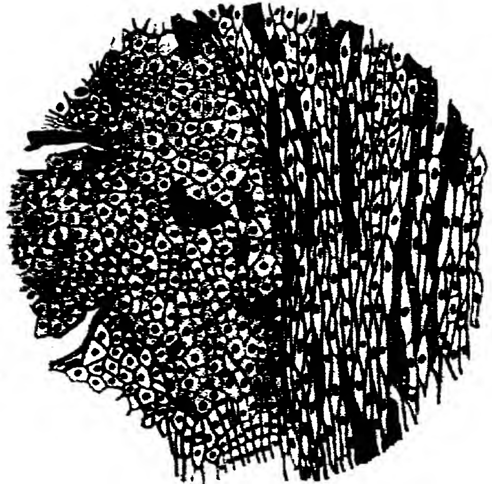

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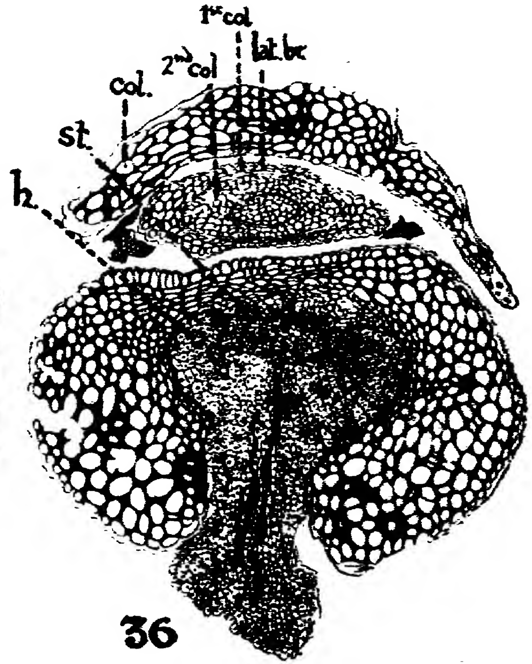

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FIG. 36.—Transverse section of *K. Lindsayi* stem immediately above a node showing a young haustorium: h.: partly surrounding stele of host stem (st.); lat. br.: lateral branch bud; 1st col. 2nd col.: two successive collars of the bud; col.: tip of collar of the lower node of host stem. × 50.

FIG. 37.—Longit. section of *K. Lindsayi* stem with a seedling *K. Lindsayi* haustorium. Cell contents are stippled in the haustorial cells. × 90.

FIG. 38.—Transverse section part of a *K. Lindsayi* internode showing the young haustorium of a *K. Lindsayi* seedling. Nuclei are drawn in the haustorial cells; c.v. and s.v.: vascular elements belonging to the host; f.: fibre of host separated from the vascular elements by secondary growth of the haustorium at the point marked 2°. × 90.

Some Characteristics of "Limonites" Used in the Cure and Prevention of Bush Sickness.

By R. E. R. GRIMMETT, M.Sc., AND F. B. SHORLAND, M.Sc.

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INTRODUCTION.

THE hydrated oxides of iron occurring in nature have been variously and somewhat indefinitely classified both mineralogically and chemically. Posnjak and Merwin (1919) list the following series as having been described as minerals, stating that goethite alone has been well defined:—

Turgite	$2\ Fe_2O_3\ H_2O$.
Goethite, Lepidocrocite	$Fe_2O_3\ H_2O$.
Hydrogoethite	$3\ Fe_2O_3\ 4\ H_2O$.
Limonite	$2\ Fe_2O_3\ 3\ H_2O$.
Xanthosiderite	$Fe_2O_3\ 2\ H_2O$.
Limnite	$Fe_2O_3\ 3\ H_2O$.

There are also two anhydrous oxides, haematite (Fe_2O_3) and magnetite (Fe_3O_4), of which the latter does not concern us here. Clarke (1924) does not recognise hydrogoethite, while Friend (1921) also lists esmeraldaite $Fe_2O_3\ 4\ H_2O$.

From their optical, physical, and chemical studies of the various natural and synthetic hydrous oxides Posnjak and Merwin conclude that only the monohydrate has a definite chemical existence, occurring in the two crystalline forms of goethite and lepidocrocite, and with various amounts of adsorbed water, in amorphous form as limonite and the other supposed higher hydrates. They also find turgite to be a solid solution of hydrous haematite and the monohydrate. Weiser (1926) concurs in these views and concludes that the yellow crystalline monohydrate prepared by these authors is identical with goethite. He also considers that the yellow hydrated oxide prepared by Tommasi by the oxidation of hydrous ferrous oxide is the monohydrate. This yellow synthetic hydrated oxide does not lose water on prolonged boiling at 100° C. and is only sparingly soluble in concentrated acids. The red-brown hydrous oxide obtained by precipitating a ferric salt with alkali is very soluble in dilute acids, but is dehydrated even by boiling water. A brick-red oxide is produced by prolonged boiling of ferric acetate. This modification is nearly insoluble in concentrated nitric or hydrochloric acids, but "dissolves" (sol formation) in dilute acids, being reprecipitated by the addition of concentrated acid.

Posnjak and Merwin (1919), working with selected type specimens containing generally less than 5 per cent. of impurities showed that in many cases the geological classification did not agree

with that found by analysis, the discrepancies being generally increased by allowing for the water of hydration and impurities such as silica.

With these facts in mind the difficulty of determining the exact mineralogical status of the hydrous iron oxide in the various deposits and preparations of New Zealand " limonites " used for stock feeding purposes, and which generally contain from 10 to 20 per cent. of impurities, can be appreciated. It is also apparent that the mode of formation may greatly influence the solubilities of hydrated iron oxides of approximately the same chemical composition. Naturally occurring hydrated iron oxides may be formed in several ways, as, for instance, by the oxidation and leaching of iron sulphides, precipitation from solution by alkaline waters, and the oxidation of ferrous carbonate by iron bacteria

Experimental.

Ore from four different sources has been ground and used in experiments on the cure and prevention of bush sickness. That from Ruatangata (Whangarei), much of which is earthy in texture and of light brownish-yellow colour, when crushed and screened with only a preliminary air-drying, has given uniformly good results.*

Ore from Puhipuhi of more compact texture and darker colour appears to have given some good results when treated similarly to the Ruatangata product, but when finely ground in a cement mill during which process it was heated (as shown by the reddish colour and low combined water and from information received) and became mixed with several per cent. of calcium carbonate, it was generally a failure.

Onekaka ore which is compact and dark coloured has not yet been tried in a merely air-dried and ground condition. Some which is known to have been heated was definitely unsuccessful in preventing bush sickness.

Feeding experiments with Okaihau ore have not yet proceeded far enough to indicate its relative efficiency when compared with the Ruatangata material, but some favourable reports have been received.† The ground product is a duller brown than any of the others, but the analysis shows it to be high in combined water.

* For a full account of the field evidence and previous literature, see article on "Control of Bush Sickness in Sheep," by B. C. Aston, *N.Z. Jour. Agric.*, June, 1932.

† Since the above was written, Okaihau finely ground, air dried limonite has been found by Mr C. R. Taylor to be fully efficacious in preventing bush sickness in sheep.

Complete analyses of the Puhipuhi and Onekaka ores have been made by Mr Seelye and are given herewith by courtesy of the Dominion Analyst:—

FUSION ANALYSIS OF ONEKAKA AND PUHIPUHI ORES BY MR SEELYE.

		Puhipuhi
Silica (SiO_2)		
Alumina (Al_2O_3)		2.54
Ferric oxide (Fe_2O_3) .. .		71.25
Magnesia (MgO)		0.08
Calcium oxide (CaO) ..		0.65
Sodium oxide (Na_2O) ..		trace
Potassium oxide (K_2O) ..		0.02
Phosphorus pentoxide (P_2O_5)		0.40
Titanium dioxide (TiO_2) ..		0.40
Manganese dioxide (MnO_2)		2.45
Chromium sesquioxide (Cr_2O_3)		none
Cupric oxide (CuO)		not found
Nickelous oxide (NiO) ..		trace
Cobaltous oxide (CoO) ..		trace
Antimony trioxide (Sb_2O_3) .		0.04
Arsenic trioxide (As_2O_3) ..		0.033
Barium oxide (BaO) .		0.27
Sulphur (S)		0.16
Carbon dioxide (Co_2)		0.49
Moisture		3.20
Loss on ignition		12.12
	100.52	100.43
Oxygen correction	0.18	
FeO	100.34	

Fusion analysis of Ruatangata and Okaihau samples made in this laboratory are as follows:—

	A/1115. Ruatangata.	D/1397. Okaihau.
Silica (SiO_2)	7.79	2.17
Alumina (Al_2O_3)	5.24	7.16
Ferric oxide (Fe_2O_3)	62.30	67.45
Alkalis (K_2O, Na_2O) ..	trace	trace
Calcium oxide (CaO) ..	0.58	0.56
Magnesia (MgO)	0.05	0.13
Titanium dioxide (TiO_2) ..	0.31	0.62
Manganese dioxide (MnO_2)	0.79	0.24
Chromium sesquioxide (Cr_2O_3)	not found	not found
Cupric oxide (CuO)	0.08	0.07
Nickelous oxide (NiO) ..	0.01	0.01
Cobaltous oxide (CoO) ..	trace	trace
Antimony trioxide (Sb_2O_3)	not found	not found
Arsenic trioxide (As_2O_3) ..	trace	trace
Sulphur (S)	not found	0.16
Phosphorus pentoxide (P_2O_5)	0.82	1.79
Moisture	9.59	5.88
Loss on ignition	13.01	14.07
	100.57	100.31

It does not appear that such differences between the ores as are shown in these analyses are adequate to account for the great variations in their curative properties.

TABLE I.

The Chemical Composition and Characteristics of Some Typical Limonites used in Stock Feeding.

Lab. No.	% Moisture (dried at 100° C. for 24 hours).	% Loss on Ignition.	Combined water calculated to 100% hydrated iron oxide.	% Iron Oxide:		% Calcium carbonate ($CaCO_3$) limestone (titration) method.	Solubility in sugar-hydrochloric acid solution. % Fe_2O_3 dissolved.	Colour. Ridgway's "Colour Standards," 1912.	Remarks.
				Fe_2O_3.	FeO.				
D/771	2.82	11.85	12.5	72.6	0.05	3.4	0.94	Between Argus and Sudan brown	Farmer "H." Atiamuri
D/772	2.92	12.40	13.4	71.7	trace	2.9	0.69	Sudan brown	Farmer "H." Atiamuri
D/773	1.68	10.63	10.7	73.8	trace	4.1	1.14	Argus brown	Farmer "P." Putaruru
D/774	3.87	13.50	14.3	72.6	0.23	3.2	0.84	Antique brown	Farmer "N." Tokoroa
D/838	2.58	14.01	15.6	70.8	trace	2.1	0.92	Argus brown	Farmer "P." Putaruru
D/846	2.48	13.16	13.3	70.6	trace	5.4	1.17	Argus brown	Dairy Factory, Tokoroa
Average:	2.72	12.59	13.3	72.0	0.05	3.6	0.95		

Puhipuhi limonites. Reported inefficient in field trials. (Ground in cement mill)

TABLE I.—*Continued.*

THE CHEMICAL COMPOSITION AND CHARACTERISTICS OF SOME TYPICAL LIMONITES USED IN STOCK FEEDING.

Lab. No.	% Moisture (dried at 100° C. for 24 hours).	% Loss on Ignition.	Combined water calculated to 100% hydrated iron oxide.	% Iron Oxide: Fe_2O_3.	% Iron Oxide: FeO.	% Calcium carbonate ($CaCo_3$) limestone (titration) method.	Solubility in sugar-hydrochloric acid solution. % Fe_2O_3 dissolved	Colour. Ridgway's "Colour Standards." 1912.	Remarks.
D/446	2.77	13.50	15.9	67.6	0.27	1.6	0.66	Sudan brown	Representative sample early grinding Puhipuhi.
D/832	2.20	14.62	16.8	66.6	trace	2.4	0.54	Between Argus and Brussels brown	Untested in field. Puhipuhi.
D/844	3.20	15.03	17.2	71.2	trace	0.4	0.52	Brussels brown	Tokaroa factory. Reputed good results cattle. Puhipuhi.
A/1115	9.59	13.01	16.6	62.3	0.28	1.3	2.86	Between Brussels and Antique brown	Farmer "H," Atiamuri.
D/837	7.96	14.40	16.2	71.8	0.29	1.2	2.20	Between Mars yellow and Antique brown	Farmer "N." Tokoroa.
D/840	9.53	14.34	16 9	68.2	0 28	0.9	2 54	Antique brown	Factory. Tokoroa
D/842	7.52	14.33	16 3	72.3	0.33	0.6	2.22	Antique brown	Farmer "N," Tokoroa.

Ruatangata limonite. (Crushed and screened) Good.

TABLE I.—*Continued.*

THE CHEMICAL COMPOSITION AND CHARACTERISTICS OF SOME TYPICAL LIMONITES USED IN STOCK FEEDING.

Lab. No.	% Moisture (dried at 100° C. for 24 hours).	% Loss on Ignition.	Combined water calculated to 100% hydrated iron oxide.	% Iron Oxide: Fe_2O_3	% Iron Oxide: FeO.	% Calcium carbonate ($CaCo_3$) limestone (titration) method.	Solubility in sugar-hydrochloric acid solution. % Fe_2O_3 dissolved.	Colour. Ridgway's "Colour Standards" 1912	Remarks
D/843	8.20	14.38	16.8	70.1	1.55	0.6	3.26	Raw sienna	Farmer "H." Atiamuri } Ruatangata limonite (Crushed and screened) Good
D/845	7.85	12.76	16.0	71.6	0.31	0.4	2.10	Between Antique and Brussels brown	Farmer "P." Putaruru } Ruatangata limonite (Crushed and screened) Good
Average:	8.44	13.87	16.3	69.4	0.52	0.8	2.53		
D/724	7.32	13.63	16.6	68.2	0.36	trace	3.06	Antique brown	Representative sample. Ruatangata.
D/776	5.89	13.83	15.7	69.8	0.33	1.8	1.72	Argus brown	Ruatangata heated. Untested in field.
D/736	3.21	11.63	11.1	71.4	trace	0.1	3.44	Antique brown	Ruatangata ground by Fertilizer Co.
C/919	1.86	10.16	13.4	63.0	0.10	0.9	1.14	Between Brussels and Argus brown	Onekaka. Untested in field.
D/777	5.60	14.50	18.2	64.1	0.17	0.4	1.14	Brussels brown	Okaihau. Untested in field.
D/980	5.39	13.31	16.2	66.8	0.32	1.0	1.07	Between Brussels brown and Argus brown	Okaihau. Untested in field.

A number of commercial samples of " limonite " having known histories in the treatment of bush sickness were therefore collected from farms by Mr B. C. Aston and Mr C. R. Taylor, Analyst's assistant at Rotorua, and together with specimens of the original ores, were submittd to partial analysis and to a number of special tests in an attempt to correlate nutritional efficacy with physical and chemical characteristics, and especially with the rate of solubility under conditions resembling those which might be met with in the ruminant digestive system.

The preliminary data obtained from a general survey of the samples are shown in Table I. In cases where several samples of the same or closely similar material were examined with concordant results, representative analyses only are given. For some of these samples no definite field reports are available; these, however, have been included, as they indicate the general uniformity of the samples received from the same source. From the groups indicated by the preliminary data, typical samples were selected for further study, the results being shown in the subsequent tables.

It will be seen that in the majority of cases where a sample had proved ineffective it was found to have both a low combined water and a high calcium carbonate content.

In the case of the commercial Onekaka sample with low combined water and low calcium carbonate content, no feeding test with unheated material has been made.

It is evident that if the rate at which the dilute gastric hydrochloric acid came into contact with the solid particles of lick were less than the rate at which it could dissolve the calcium carbonate, the iron oxide would probably be attacked only very slowly until all the lime had gone into solution. It is interesting to note in this connection the great difference in conditions obtaining in the ruminant and non ruminant stomachs respectively. In the ruminant the pretreatment of the vegetable food in the rumen together with large quantities of saliva results in the production of a considerable amount of alkali carbonates. On passage of the liquid material into the fourth stomach a large quantity of gastric hydrochloric acid must be used up in neutralising this carbonate before the contents can become acid. In an actual case of a sheep still warm (killed less than 1 hour) the rumen was filled with about 2 litres of green liquid (finely divided grass) having an alkalinity equal to N/8. The fourth stomach contained about 500 cc. of liquid, also strongly alkaline, so that apparently some time elapses before neutralisation takes place. In the contents of a second stomach examined, an acidity of N/30 was found. As the gastric juice has only about the same normality, it would seem that it must eventually be considerably more diluted than in the case of the non-ruminant where only a slight alkalinity due to the saliva has to be neutralised. It is worth

noting this point when considering the fact that ruminant animals are much more susceptible to bush sickness or iron starvation than non-ruminants.

In some experiments in which the quantities of dilute (0.36 per cent.) HCl and of limonite were so arranged that the calcium carbonate present materially reduced the concentration of acid, an inverse relationship was found between the amount of iron dissolved and the percentage of $CaCO_3$. When the total quantity of the same strength HCl was so increased that the effect became negligible the amount of iron dissolved showed no correlation either with the field evidence or the analytical data.

A case has recently come under notice where Ruatangata limonite only was used for sheep and cattle on a Tokoroa farm. After initial good results, a considerable number of sheep commenced to lose condition. It was then found that carbonate of lime had been added to the limonite with the idea of improving the lick. On omitting the lime good results were once more obtained with the sheep. Cattle were not affected.

While, however, admixture of carbonate of lime may quite well be one factor in rendering " limonite " unassimilable, it is not the only one, as is shown by the case of the Onekaka ore* (heated).

Results by the " available iron " oxalic acid method suggested by Seelye and adopted by Rigg and co-workers (1932) showed relatively high solubility for all samples, and the differences between those proved to be effective and those proved to be ineffective did not seem to have great significance (Table II).

TABLE II.

RELATIVE SOLUBILITIES OF LIMONITE SAMPLES IN N/10 OXALIC ACID.*

Lab. No.	% Fe_2O_3.	Remarks.
A/1115	11.4	Ruatangata, coarsely screened, good results
D/742	11.5	,, very finely ground
D/725	13.0	,, representative sample
D/736	11.9	,, ground in cement mill, heated
D/771	7.8	Puhipuhi, ground in cement mill, ineffective Farmer " H," Atiamuri
D/773	8.6	,, ditto. Farmer " P," Putaruru
D/774	9.8	,, ditto. Farmer " N," Tokoroa

* Analysis by Mr D. F. Waters.

As it did not seem likely from these results that the differences in the availability of the various samples of limonite could be correlated with their solubility simply under varying conditions of

* Since this paper was written, an article by Rigg and Askew has appeared in *Empire Journal of Experimental Agriculture*, Vol. 11, No. 5, January, 1934, on "Soil and Mineral Supplements in the Treatment of Bush Sickness." In a course of feeding experiments with sheep on bush sick pasture at Glenhope, it was found that good results were obtained with drenches of Nelson garden soil and iron ammonium citrate, whereas typical bush sickness developed in control group and the group drenched with Onekaka limonite. The conclusion is reached that the failure of Onekaka limonite to overcome bush sickness shows that "the supply solely of iron containing compounds is not sufficient for the prevention of ailment." At the same time, it is stated that the (efficacious) iron ammonium citrate used for drenching was chemically pure.

acidity, it was thought that some other factor, such as rate of solution rather than solubility at equilibrium, or susceptibility to reducing agents, might be concerned.

In some preliminary experiments it was found that the stomach semi-liquid contents of sheep had a reducing action equivalent to between N/100 and N/200 iodine. This is a matter of importance, since Johnson (1924) has shown that ferrous oxide is much more soluble in dilute hydrochloric acid than ferric oxide. Moreover, in the present investigation we have found that the addition of a mild reducing agent to dilute hydrochloric acid greatly enhanced the solubility of the limonite, while in a buffered acetic acid solution (pH 4.0) in which the limonite was practically insoluble the addition of sodium hydrosulphite not only rendered the limonite readily soluble, but within limits the amount of iron dissolved was directly proportional to the amount of reducing agent added (see Table III and graph). It was thought that further information on the relative susceptibilities of the limonites to reducing agents might explain to some extent the wide differences in the efficacy of the limonites as shown in the field tests. Three series of experiments were therefore devised to evaluate the solubilities of the limonites, using as reagents sugar-hydrochloric acid, acetic-sodium hydrosulphite, and hydrogen sulphide solutions respectively.

(a) *Solubility of Limonite in Sugar-Hydrochloric Acid.*

The reagent for this experiment was prepared by dissolving 100 grams of commercial sucrose in one litre of N/10 hydrochloric acid made up from freshly boiled distilled water. In order to facilitate inversion the sugar was added while the solution was still hot. In the solubility test 0.5 gram of limonite was placed in a 200 cc. conical flask with 50 cc. of the reagent and immediately stoppered with a tight fitting cork provided with a bunsen valve to protect the solution fom oxidation by air. After shaking the flask in boiling water for a period of 15 minutes, the solution was quickly cooled, made up to 100 cc. with distilled water, and immediately filtered through a No. 42 Whatman paper. After 20 cc. of filtrate had been collected the funnels and filter papers were removed to exclude the possibility of further solution of the limonite, and a suitable aliquot taken for the iron estimation. It was found that by keeping strictly to the above conditions duplicate samples yielded concordant results.

On reference to Table I it will be seen that all the efficacious samples (as judged from the yield of milk in the case of cows or from increase of weight in the case of sheep) of manufactured Ruatangata limonite had a solubility several times greater than the average of the relatively ineffective manufactured Puhipuhi limonite samples. The Onekaka (heated) sample also had a low solubility. It was found, however, that the Puhipuhi ore as mined had a low solubility as did an early sample of ground and apparently unheated material from the same locality which was reported to have given good results at

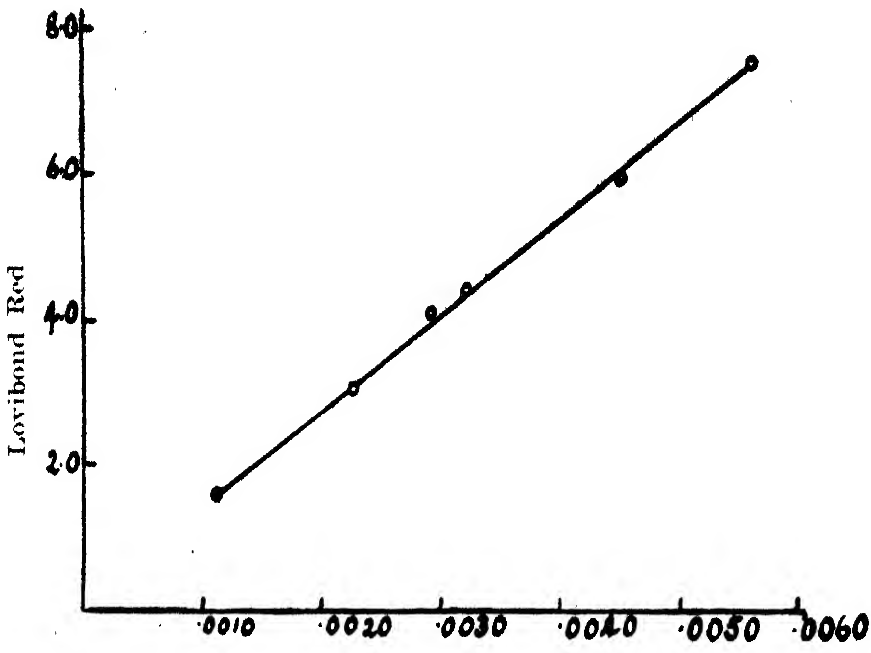
Tokoroa on cattle. Low figures were also obtained for the manufactured Okaihau product. A sample of the iron oxide (haematite) used successfully with cattle in Kenya Colony gave a very low solubility.

(b) *The Solubility of Limonite in Acetic Acid-Sodium Acetate Solution containing Sodium Hydrosulphite as a Reducing Agent.*

Elvehjem, Hart and Sherman (1933) have devised a chemical method for determining the biologically available iron of foods. Their method depends on the fact that under specified conditions an acetic acid-sodium acetate buffer solution containing sodium hydrosulphite will dissolve out " available " iron, while the iron bound in complex form such as haematin iron which is unavailable for haemoglobin formation is not attacked by this reagent. The chemical method yielded in the hands of these workers results in good agreement with those obtained from animal feeding experiments. It was hoped that this method would give a measure of the biological efficiency of the various limonites. Actually, as shown in Table III, when the limonites are treated according to the Elvehjem, Hart and Sherman method no differences between the various limonites were found, each limonite having the same amount of soluble iron in equilibrium with the reagent.

As the total solubility did not discriminate between the different limonites it was decided to measure the rate of solubility according to the following method. 0.25 gram of limonite was weighed into a test-tube with 0.25 gram of sodium hydrosulphite. 20 cc. of acetic-sodium acetate solution (buffered to pH 4.0) were rapidly transferred from a measuring cylinder into the test-tube and the time noted. The test-tube was then corked as rapidly as possible and vigorously shaken until 10 seconds before the appointed time, when the solution was filtered through a No. 42 Whatman paper, the filtrate being removed 10 seconds after the appointed time. In the case of the 15 seconds period the filtration proceeded for only 10 seconds, so that the aliquot available for analysis amounted to less than 1 cc., necessitating the use of a serum pipette. For the other time intervals a 1 cc. aliquot was taken for the estimation. The iron estimation was made according to Hill's (1931) $\alpha\,\alpha'$ dipyridyl method. The method as originally outlined was not suitable for the present investigation and certain modifications were introduced. It was found that the iron dipyridyl colour could be readily measured on the Lovibond tintometer. Measured volumes of standard 2M/10,000 ferrous ammonium sulphate were added to a measured excess of the 12M/10,000 standard $\alpha\,\alpha'$ dipyridyl solution so as to produce concentrations of iron varying from 0.0010 to 0.0060 mgm. of iron per cc. On plotting the concentration of iron against the Lovibond red units a straight line was obtained as shown below in Graph I.

GRAPH I.



The red colour within the limits of the concentrations measured is thus directly proportional to the concentration of the iron in solution.

TABLE III.

THE EFFECT OF SODIUM HYDROSULPHITE ON THE SOLUBILITY OF LIMONITE IN AN ACETIC ACID-SODIUM ACETATE BUFFER SOLUTION (pH 4.0).

	% Iron Dissolved (as Fe_2O_3) at Equilibrium.			
Lab. No.	No reducing agent.	1.25% reducing agent.	2.5% reducing agent.	3.75% reducing agent.
A/1115 (Ruatangata)	0.0	22.4	36.5	52.5
D/725 (Ruatangata)	0.0	23.1	41.2	52.5
D/773 (Puhipuhi)	0.0	22.3	41.2	50.4
D/844 (Puhipuhi)	0.0	22.0	34.3	54.9
C/919 (Onekaka)	0.0	23.4	36.5	sample all used.

GRAPH 2.

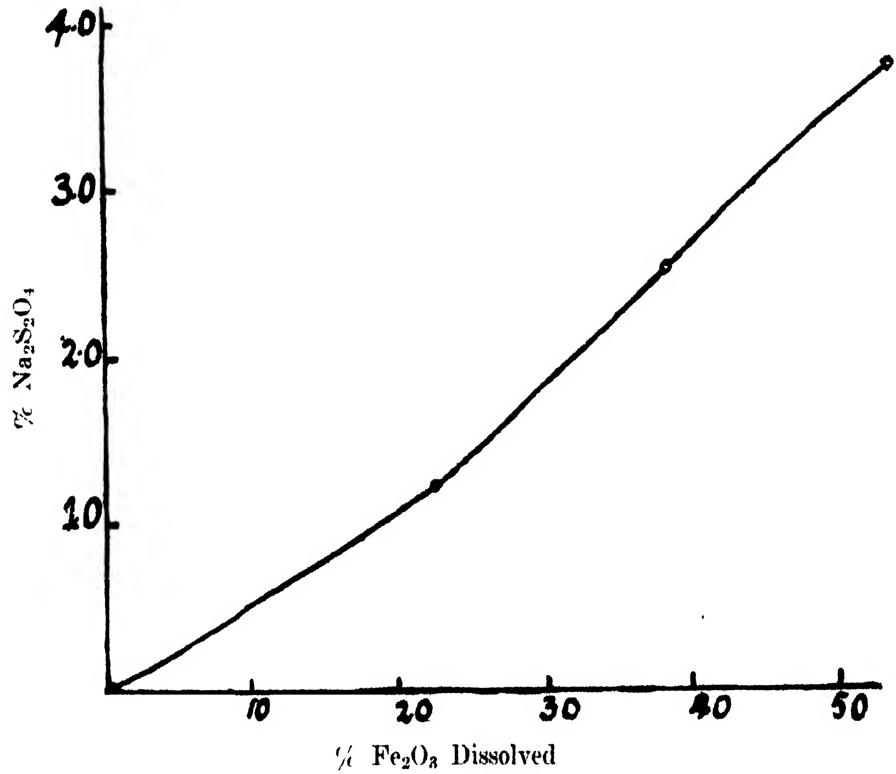


TABLE IV.

THE RATE OF SOLUBILITY OF LIMONITE IN A pH 4.0 BUFFER SOLUTION CONTAINING 1.25% SODIUM HYDROSULPHITE.

% Fe_2O_3 dissolved.

Lab. No.	15 secs.	30 secs.	60 secs.	90 secs.	5 mins.	1 hour.
A/1115 (Ruatangata)	5.1	8.9	14.7	18.3	22.4	22.3
D/724 (Ruatangata)	7.8	10.3	20.8	21.8	24.5	23.1
D/773 (Puhipuhi)	2.1	5.5	11.2	13.0	20.2	22.3
D/844 (Puhipuhi)	1.6	3.9	7.8	9.2	22.8	22.8
C/919 (Onekaka)	1.4	3.7	9.8	sample all used.	23.4	23.4

It will be observed from the above table that although all the limonites reached equilibrium with the solvent in approximately five minutes they approach equilibrium at a different rate. The discriminating factor between the various limonites does not therefore depend on the solubility at equilibrium, but on the rate of solution. Under these circumstances the most suitable period of solution for a comparison of limonites is the shortest period which can be accurately and conveniently measured. It was found that a 30 second period gave good agreement between duplicate determinations and could be adopted as a useful standard for comparison. It is interesting to note that the hydrosulphite method yields similar differences between the various limonites to those given by sugar-hydrochloric acid method.

(c) *The Effect of Hydrogen Sulphide on the Solubility of Limonite in Hydrochloric Acid.*

It is well known that when hydrated iron oxide is treated with hydrogen sulphide in neutral solution it becomes dark coloured, H_2S being removed from solution to form iron sulphide. According to Thorpe's Dictionary of Applied Chemistry (1921 edition) the reaction $Fe_2O_3 + xH_2O + 3H_2S = 2\ FeS + S + (x + 3)\ H_2O$. takes place in neutral or faintly acid solutions, while in weakly alkaline solutions the reaction is $Fe_2O_3 + xH_2O + 3H_2S = Fe_2S_3 + (x + 3)\ H_2O$. In strongly acid or alkaline solution the reactions are inhibited. With natural hydrated iron oxides the extent to which the reactions proceed varies enormously. The highly hydrated earthy samples take up large quantities of H_2S while the hard, less hydrated ores approaching haematite in composition are much less affected.

In preliminary experiments the various materials used in the stock-feeding trials gave markedly different results when tested for their capacity for absorbing H_2S, and after such treatment similar differences were apparent in their solubility in dilute (0.36 per cent.) hydrochloric acid. It was found that if the acid and H_2S were added simultaneously very little iron was dissolved. The colours given by the fine suspensions of the limonites after treatment with H_2S, when examined by reflected light, afford an interesting method of differentiating between the various deposits, the original colour of the sample (as affected by heating in the cement mill, or by fineness of grinding) appearing to make little difference.

The following method was adopted for estimating the relative effect of H_2S on the solubility of limonites in dilute HCl:—0.5 gm. limonite is shaken for 30 minutes with 80 cc. N/20 freshly prepared H_2S solution in a closely stoppered flask or test-tube of 100 cc. capacity. 10 cc. of N, HCl are then added and the mixture shaken for a further 10 minutes. It is then filtered through a dry paper and the iron determined on a suitable aliquot. Duplicates were found to agree closely. Some typical results are given in Table V.

TABLE V.

EFFECT OF TREATMENT WITH H_2S ON THE SOLUBILITY OF LIMONITE.

Lab. No.	Colour of H_2S Suspension.	% Fe_2O_3 Dissolved in 0.40 Hcl.	Remarks.
D/771	grey (purplish)	7.7	Puhipuhi. Relatively ineffective.
D/772	grey	5.9	" " "
D/774	grey	5.0	" " "
D/838	black (purplish)	8.4	" " "
D/446	grey	4.8	" Early grinding.
——	grey (purplish)	5.2	" Ore.
A/1115	purple (bright)	16.7	Ruatangata. Good.
D/725	" "	22.0	" "
D/698	" "	22.8	" "
D/810	" "	20.9	" Ore.
D/742	navy blue	22.0	Ground by Fertilizer Company.
D/776	purple	20.2	" " "
D/1502	purple (dull)	5.8	Onekaka. Relatively ineffective.
D/1007	bright red	0.5	Haematite. Kenya Colony.
D/1468	purple	31.9	"Lux" imported for gas purification.

It will be seen that the solubilities given by this method follow the same general order as with methods A and B, but the discrimination between the samples is wider.

Discussion of Solubility Results obtained by Methods A, B and C.

Consideration of the results under sections A, B and C suggests strongly that the differences in efficacy between the various types of iron oxide used in feeding trials are a matter of degree only. As there are also degrees of bush sickness, both in the capacity of various types of soil for producing the disease, and in the response of the different classes of livestock on any one deficient area, it is evident that close correlation of field and laboratory data cannot be expected except in cases where feeding experiments with the different products have been carried out in one locality using similar minerals.

There is evidence from experiments conducted by the Rowett Institute on Nakuruitis (Orr and Holm 1931) (a deficiency disease closely related to bush sickness and affecting cattle on the volcanic soil of Nakuru in Kenya Colony) that the quantity of iron oxide consumed is a very important factor in the prevention and cure of the disease The control and low iron diet groups showed all the typical symptoms of Nakuruitis. The third group were in normal condition, while the fourth group, which received approximately two and a-half times the amount of iron consumed by the third group, were in prime condition, having gained more than double the weight of that group.

In the case of enzootic marasmus, an iron deficiency disease possibly identical with bush sickness and affecting the sheep and cattle of the Denmark district in Western Australia, Filmer (1933) has shown that the curative dose of iron may vary enormously according to the iron compound used. The effective dose for sheep was found to vary from 02 gram to 11 grams per head per day for dried liver extract and limonite respectively. In the experiments with ferrous carbonate it was shown that the availability of the iron differed considerably according to the source of the material. Whereas daily doses of iron carbonate in the form of spathic iron ore containing as much as 2.8 grams of iron were ineffective in combating the disease, Blaud's pills also containing iron as ferrous carbonate were effective in daily doses corresponding to 1.16 grams of iron. Experiments on calves with various iron compounds gave results similar to those obtained for the sheep

As the bulk of the iron is excreted in the faeces it is difficult to account for the greater efficacy of large amounts of iron unless a "large head of iron" in the intestine is necessary to secure the absorption of the relatively small amounts required for haemoglobin formation, Morris (1933) In considering the therapeutic value of the dried liver preparation Filmer has estimated that the addition of iron present in such a preparation would in the case of his experiments amount to the addition of one-twentieth of the iron normally present in the unsound pasture and it therefore seems unlikely that the iron content of the dried liver is the major curative factor. To explain this anomaly Filmer has put forward the hypothesis that

the effectiveness of the various iron compounds depends on the presence of some unknown mineral necessary for the metabolism of iron. In our opinion such a hypothesis does not seem to be justified; for pure iron compounds such as iron and ammonium citrate effectively cure enzootic marasmus as well as bush sickness. According to Reakes and Aston (1919) pure iron tartrate and iron acetate* are also efficacious in curing bush sickness. Moreover, a fusion analysis of the effective Ruatangata limonite used in our experiments did not reveal the presence of any element which is not normally present in the pasture.

In view of the greater effectiveness of ferrous iron as compared with ferric iron as a cure for certain forms of anaemia, Morris (1933), and in the light of our present investigations which show limonites to be much more readily soluble in acid solution in the presence of reducing agents, we would suggest the possibility that the effectiveness of liver preparations as a cure for enzootic marasmus is due to the presence of reducing substances such as glutathione normally present in the liver enhancing the solubility of the otherwise unavailable iron present in the unsound pasture. Such a suggestion might also explain the enhancing effect of the dried stomach preparations when used in conjunction with iron and ammonium citrate and the fact that dried pig's stomach alone gave no response when administered to lambs suffering from enzootic marasmus. The ineffectiveness of liver ash can be similarly interpreted.

Although no field tests have been made in New Zealand to ascertain the minimum quantity of limonite necessary to maintain the health of the stock, it appears from the report of a sheep farmer at Puketurua, who obtained excellent results when his stock were fed with the Ruatangata limonite, but poor effects with the Puhipuhi limonite when fed at the same rate, that the severity of the bush sickness was checked to some extent by increasing the inferior limonite in the salt lick from 50 per cent. to 80 per cent.

In conclusion it thus seems possible that there is a critical value in the quantity of iron necessary to keep the stock healthy. This value would naturally vary with the nature of the limonite and with the ruminant under consideration. Thus sheep appear to be more susceptible to bush sickness than cows.

The Effect of Heating on the Physical and Chemical Properties of Limonite.

Apart from the earlier work of Fisher (1910) and the later and more extensive investigations of Posnjak and Merwin (1919) on the dehydration of limonite and other hydrous hydrated iron oxides, there appears to have been no precise record of the physical and chemical changes which take place when these oxides are heated.

* Personal communication.

Fisher has shown that in the case of limonite, water is lost rapidly below 100° and then sparingly although continuously up to 165°, at which temperature the monohydrate appears to be stable. Above this temperature the yellow monohydrate decomposes to form red haematite. Recent investigations, however, suggest that a definite transition temperature of the monohydrate to the anhydrous oxide has not been established.

Actually the detection of ferric oxide hydrates is complicated by the fact that the hydration of ferric oxide is irreversible, preventing the application of usual methods such as the measurement of the vapour pressure of the hydrate at constant temperature where it can be shown by the phase rule that the composition of each new hydrate will be accompanied by a sudden decrease in vapour pressure. In order to avoid this difficulty Posnjak and Merwin applied the LeChatelier method for irreversibly hydrated substances to the study of limonite and related iron ores. The method consists essentially in measuring the temperature at definite intervals of time while the substance is heated at a uniform rate. If no chemical or physical change occurs, a straight line graph is obtained on plotting the temperature against time. If, however, a chemical or physical change occurs, it is accompanied by the absorption or evolution of heat, and in place of a straight line, a curve (the sharpness of which depends on the stability of the component or components concerned in the transition) is shown on the graph at the decomposition temperature. The hydrous hydrated oxides of iron were shown by this method to have a decomposition temperature of approximately 300°. This figure is considerably higher than obtained by Fisher from simple dehydration. Posnjak and Merwin attribute the difference to the slow rate of reaction and physical condition of the limonite.

Posnjak and Merwin also studied the dehydration by heating the minerals to constant weight at fixed temperatures. The curves obtained by plotting the percentage of water against the temperature were found to consist of three distinct parts, the middle portion of which was considered to be due to the decomposition of the monohydrate, while the upper and lower portions of the curve probably corresponded to the capillary and adsorbed water.

It is well known that hydrated iron oxides on strong ignition become much less soluble in concentrated hydrochloric acid, but so far as the authors are aware no quantitative measurements have been made, and in view of the fact that certain ineffective limonites were known to have been heated, it was decided to make a systematic survey of the changes in the solubility, specific gravity, and hydration of representative samples when heated to a definite temperature for a known period of time. The results of this investigation are presented in the table below.

TABLE VI.

THE EFFECT OF HEATING ON THE CHEMICAL AND PHYSICAL PROPERTIES OF LIMONITE.

Sample.		Solubility in sugar-hydrochloric acid.	Solubility. ratio heated / Unheated sample.	Specific gravity at 20°.	% H_2O (free and combined).	Remarks
A/1115—	as received	2.86	—	2.80	22.0	Good limonite from Ruatangata deposits. Used by Farmer "H" at Atiamuri.
„	heated to 100° for 24 hours.	2.92	1.02	2.95	12.4	
„	heated to 184° for 1½ hours.	3.74	1.31	3.26	10.8	
„	heated to 290° for 1½ hours.	3.00	1.05	3.61	1.8	
„	heated on blowpipe for 10 mins.	0.08	0.028	4.16	0.0	
D/724—	as received	3.06	—	2.97	21.0	Representative sample from Ruatangata deposits.
„	heated to 100° for 24 hours.	3.06	1.00	3.10	13.6	
„	heated to 184° for 1½ hours.	3.76	1.23	3.39	11.6	
„	heated to 290° for 1½ hours.	3.06	1.00	3.95	3.4	
„	heated on blowpipe for 10 mins.	0.09	0.029	4.47	0.0	
D/773—	as received	1.14	—	3.58	10.5	Ineffective limonite from Puhipuhi deposits. Used by Farmer "P," Putaruru.
„	heated to 100° for 24 hours.	—	—	3.67	8.8	
„	heated to 184° for 1½ hours.	1.14	1.00	3.86	8.3	
„	heated to 290° for 1½ hours.	2.08	1.83	4.03	3.0	
„	heated on blowpipe for 10 mins.	0.68	0.60	4.37	0.0	
D/446—	as received	0.66	—	3.42	15.6	Representative sample from Puhipuhi deposit.
„	heated to 100° for 24 hours.	0.66	1.00	3.46	12.8	
„	heated to 184° for 1½ hours.	0.79	1.19	3.84	12.1	
„	heated to 290° for 1½ hours.	0.69	1.05	3.95	5.7	
„	heated on blowpipe for 10 mins.	0.29	0.44	4.47	0.0	

The solubility of the limonites was determined according to the usual procedure except that an allowance was made for the loss of water in the heated samples by taking a weight corresponding to the same amount of ferric oxide as was present in 0.5 grams of unheated sample. In each series of solubility determinations on the heated samples the corresponding unheated samples were used as controls, thereby allowing for any difference in conditions between successive experiments. The heating at 100° was done in an electric oven, while the intermediate temperatures at 184° and 290° were obtained by permitting aniline and glycerine vapour respectively to flow around the outer surface of a test-tube containing the sample together with a small wire stirrer. As preliminary heating of the limonite in boiling distilled water or evacuation of the limonite under reduced pressure made little or no change in the observed specific gravity, the specific gravity determinations were made directly in a specific gravity bottle according to the usual method.

The samples presented in Table VI are representative of the Ruatangata and Puhipuhi deposits respectively. Sample D/773, however, has very probably been heated as is shown from its colour and low percentage of combined water. This suggestion is also supported by the small loss of water and absence of change in solubility on heating to 184° for 1½ hours. It will be observed from the table that on heating the limonites to 100° for 24 hours little or no change occurs beyond a loss of free water accompanied by a small rise in the specific gravity. With the exception of sample D/773, at 184° a further small amount of free water is lost accompanied by a disproportionate increase in specific gravity and a significant rise in solubility, suggesting an alteration of the physical or chemical nature of the limonite. On heating to 290° most of the remaining water is lost, and the solubility returns to that of the original sample except in the case of D/773, where the solubility is considerably increased. At red heat the remaining water is lost and the oxides tend to the same specific gravity while their solubilities are considerably diminished. The diminution of solubility commenced at between 500° and 600° C. in the electric muffle, and its extent is evidently characteristic of a particular ore being much more marked in the case of A/1115 than for D/446. It should also be mentioned that further heating of the iron oxide brought about no further change of solubility.

As an additional check on the source of the limonites, ores taken from the Ruatangata and Puhipuhi, Okaihau and Onekaka deposits respectively were ground in the laboratory so that 80 per cent. passed 120 mesh sieve, and analysed with the following results:—

Deposit.	Specific Gravity.	Loss on Ignition.	Moisture.	Solubility in sugar-hydrochloric acid.
Puhipuhi deposit	3.51	12.58	2.55	0.52
Ruatangata deposit	3.08	12.45	6.22	4.11
Okaihau deposit	3.19	14.07	5.87	1.74
Onekaka deposit	3.44	11.14	1.79	0.48

TABLE VII.

THE EFFECT OF FINENESS OF GRINDING ON THE SOLUBILITY OF LIMONITE IN SUGAR-HYDROCHLORIC ACID.

Fineness of Grinding	A/1115—From Ruatangata deposits Gave good results Farmer "H," Atiamuri	D/724—Representative sample from Ruatangata deposits.	D/771—From Puhipuhi deposits Farmer "H," Atiamuri.	D/446—Representative sample from Puhipuhi deposits.	D/366—Sample from Okaihau deposits.
Retained on 30 mesh	2.0	trace	trace	trace	trace
Retained on 60 mesh	29.2	0.5	trace	trace	11.0
Retained on 90 mesh	19.4	9.0	2.0	2.0	24.0
Retained on 120 mesh	5.2	9.0	3.5	4.0	9.0
Retained on 150 mesh	5.0	11.0	7.5	5.0	9.0
Retained on 200 mesh	6.0	9.0	6.0	6.0	9.0
Passed 200 mesh	33.2	61.5	81.0	83.0	38.0
Solubility in Sugar Hydrochloric Acid	2.86	3.06	0.94	0.66	1.01
Colour	Between Brussels brown and antique brown.	Antique brown.	Between argus brown and antique brown.	Sudan brown.	Brussels brown.

Fineness of grinding tests were made on several representative samples in order to correlate the fineness with solubility in sugar hydrochloric acid and with the effectiveness of the limonite as judged from field tests. In the case of a material composed of solid grains reduction of the grains by grinding would expose new surfaces, thereby increasing the solubility. If, however, the grains were composed of minute particles loosely held together so as to form porous aggregates, then further grinding within certain limits should not expose fresh surfaces and so increase the solubility. Actually, as shown in the table, the rate of solubility of the limonites depends mainly on the source of the limonite and not on the state of fineness of the particles as determined by sieving. In this connection it should be emphasized that from the point of view of palatability the limonite used for stock feeding purposes must be finely ground, as sheep will not eat gritty material. In order to test the homogeneity of the limonite, a coarse fraction retained on a 50 mesh sieve was ground to pass a 200 mesh sieve. Solubility tests showed no appreciable difference between this finely ground material and the material originally passing the 200 mesh sieve. A careful examination under the microscope of the Ruatangata and Puhipuhi limonites showed that few of the particles were massive and most possessed a porous structure, being channelled and perforated with small holes. This condition was particularly marked in the case of the Ruatangata limonite. In conclusion, it would appear that from the evidence so far available the structure of the limonite is essentially that of a porous material composed of very fine homogeneous particles

Discussion.

Hydrated iron oxides have very ill defined compositions, and in any specimen of natural ore it is difficult to determine what iron compounds are present.

In the natural deposits used for stock feeding the solubility of the iron in dilute (0.36 per cent.) hydrochloric acid was very small and irregular. When reducing agents were added the solubility was much increased, the solubility at equilibrium (in the case where hydrosulphite was used) being similar for all samples and proportional to the amount of reducing agent present.

When, however, the rate of solution in the presence of reducing agents was determined it was found to show considerable differences between the samples from different sources, samples definitely known to be highly effective in curing bush sickness yielding high figures and ineffective samples low figures. Some apparent anomalies require further field experiments for elucidation. After treatment with hydrogen sulphide, great differences were found in the solubilities of the limonites in dilute hydrochloric acid. As the H_2S could only presumably attack the surface of the particles, it appears that the chief differences between the samples are to be sought in the physical state of the finest particles constituting the aggregates. In the good samples these particles would appear to be colloidal and loosely bound together, while in the inefficient samples they are evidently bound more securely as shown from specific gravity determinations. Hence in the earthy Ruatangata material the degree of fineness of grinding, or a considerable amount of heating (complete dehydration at 500° C.) have little effect on the solubility, while in the case of the harder Puhipuhi deposit, finely ground or heated samples appear in several cases to have higher solubilities than the original ore.

According to Hawke (1926), powerful reducing reactions take place in the intestine, especially in its lower portion, and these can be measured by the amount of ferrous hydroxide produced from ferric hydroxide after passage of a test meal. Paton and Orr (1920) consider the large intestine to be the seat of important digestive and absorbtive processes in herbivores so that considering that ferrous hydroxide is slightly soluble in neutral and alkaline solutions it is feasible that some absorption of iron may take place after reduction in the lower part of the intestines. Recently Lintzel (1931) from his experiments on white rats has stressed the importance of the formation of ferrous iron before the iron can be assimilated. It will be seen therefore that ease of reducibility may be an important factor in availability to the animal of the iron in a "limonite."

Hawke states that minute solid particles of iron compounds (hydroxides) are ingested and may be carried by white blood corpuscles through the intestine membranes into the lymph. Abderhalden (1911) also mentions the same phenomenon. It is evident that for this type of assimilation only the most minute colloidal particles could be utilised and such fineness could not be attained by ordinary grinding, but would have to be a property of the ultimate constituent particles of the original deposits.

In conclusion it should be emphasized that the present investigation is intended only to give a chemical picture of the problem with a view to facilitating the future identification of limonites. The correlation of the chemical properties with the efficacy of the sample in field experiments in the present work should also enable the chemist to suggest whether or not a given limonite is suitable for stock feeding purposes. Metabolism experiments are not only expensive, but in the case of limonite, would probably give inconclusive results owing to the difficulty of discriminating between the absorbed and excreted iron and to the absence of definite knowledge of the processes of iron assimilation in the digestive system of ruminants. It is considered, however, that a thorough survey of the digestive system of the sheep for soluble iron after feeding with limonite would throw considerable light on the nature of iron assimilation and perhaps decide the relative efficacy of a given limonite for stock feeding.

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SUMMARY.

(1) Fusion analyses of Ruatangata, Puhipuhi, and Onekaka ores show that in addition to iron oxide, aluminium, silicon, and water the following elements are present in some or all of the ores, in small amounts:—Titanium, calcium, magnesium, manganese, phosphorus, sulphur, barium, sodium and potassium, together with traces of copper, chromium, arsenic, antimony, nickel and cobalt. The differences in chemical composition between the various deposits would appear, however, totally inadequate to account for the variations observed in the feeding value of the ores.

(2) The analysis of 21 limonites representative of four deposits for moisture content, loss on ignition, ferrous and ferric oxide, calcium carbonate and colour estimation show that in the majority of cases the samples found by field trials to be ineffective in preventing bush sickness in stock are low in combined water and contain appreciable amounts of calcium carbonate.

(3) The solubilities of representative samples in N/10 hydrochloric acid or in N/10 oxalic acid show no striking correlation with the field evidence.

(4) Evidence is adduced from solubility experiments in sugar-hydrochloric acid solution, sodium acetate-acetic acid buffer solutions containing hydrosulphite, and hydrochloric acid solutions, after treatment with hydrogen sulphide that the limonites are much more soluble in the presence of reducing agents. The rate of solubility evaluated

from these reagents gave consistent results, the effective Ruatangata samples showing a much greater rate of solution than the ores from the other deposits.

(5) In the case of the sodium-acetate-acetic acid buffer solution pH 4.0 in which the limonite samples are insoluble the amount of iron dissolved at equilibrium is directly proportional to the amount of sodium hydrosulphite present and practically independent of the nature of the limonite.

(6) The evidence so far obtained suggests that the variations in the feeding value of the ores are to be correlated with the rate of solution of the iron in acid reducing agents rather than with the measurements of total solubility of the iron at equilibrium.

(6a) It is therefore suggested that the rate of solution under prescribed conditions of a given limonite may prove a laboratory method of determining the relative effectiveness of that limonite for curing bush sickness.

(7) A study has been made of the effect of heat on the chemical and physical properties of limonite. No striking change of solubility occurs unless the samples have been heated about 550°.

(8) Fineness of grinding as indicated by sieving tests does not appreciably influence the solubility of limonites in sugar hydrochloric acid solution.

(9) The evidence adduced from fineness of grinding measurements, microscopical examination and solubility data supports the idea that the limonites are composed of fine particles or colloids loosely bound together to form porous aggregates. Specific gravity determinations support the idea that these particles are more closely held together in the case of the inferior samples than in the case of the more effective samples.

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The Bionomics and Anatomy of Stenoperla Prasina.
(Newman).

By G. A. H. Helson, M.Sc.

Biological Research Laboratory, Canterbury College,
Christchurch, New Zealand.

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INTRODUCTION AND HISTORICAL.

IT is the object of this paper to investigate the bionomics and anatomy of the hitherto little known, archaic, but highly specialised stone-fly, *Stenoperla prasina.*

Newman (1845) first described it as *Chloroperla prasina* from a dried specimen in the British Museum, but observed that "This large and striking species agrees but indifferently with the genus *Chloroperla*, or, indeed, with either of the restricted genera of Perlidae."

Walker (1852) placed it in the genus *Hermes*, retaining the specific name, but McLachlan (1867) finally made a new genus of Perlidae, *Stenoperla prasina*, basing his classification on the similarity between the maxillary palpi, and the distribution of the transverse veins on the posterior wings of this genus, to that of *Eusthenia.*

Hutton (1898) gives a brief description dealing only with the morphological characters both of the genus and of the species, but makes no further reference to other parts.

Hudson (1892) describes and figures it in his Manual of New Zealand Entomology. In 1904 he gives a general description of the genus, figuring the adult and the nymph. For the first time the bionomics are recorded, where he gives the type of stream in which the insect is found; its location; its food and manner of catching; and observes that it might prove fatal to young trout. A description of the larva is given together with its manner of hatching and the various places where the latter takes place. Finally, he says that the perfect insect appears in November, December, and a few in January. No detailed account of the insect is, however, attempted.

Tillyard (1921) revised the classification of the Order Perlaria based on a study of world fauna, particularly in reference to the archaic types of the Southern Hemisphere. Here the Eustheniidae are for the first time recognised as a distinct family with their

characters clearly defined. The distinguishing feature of the family, apart from its archaic structures, is that the anal area of the hind-wings is very large, its margin forming a continuous curve with the rest of the wing.

In the same paper he points out that the "larvae of an unknown species of *Stenoperla* have long been known to me as occurring quite commonly in the fast streams of the Blue Mountains and South Coast districts of New South Wales." The relation between *Stenoperla prasina* and *Diamphinoa* is so close that he proposed associating them together in a new sub-family *Stenoperlinae*, which is found in Australia, Chile, and New Zealand, and nowhere else throughout the world. Finally he splits the genus into two, naming his unknown species *Stenoperla australis*.

In 1923 he published, for the first time, a key to the family of New Zealand Perlaria, describing both the sub-families and the genus; he figures the wing venation. This classification is the one adopted in the present paper.

Imms (1925) mentions *Stenoperla* in his classification, which is based on Tillyard's, and figures Tillyard's wing venation, but makes no mention beyond this.

Tillyard (1926) figures the adult and wing venation, but does not enter into a description of it.

This concludes the review of the literature to date, from which it is seen that the knowledge of the more minute structures of this genus is very meagre, and that of the internal anatomy is entirely lacking.

Classification.

PERLARIA

Capniidae Pteronarcidae Perlidae Eustheniidae Austroperlidae Leptoperlidae Nemouridae

Thaumatoperlinae Stenoperlinae Eustheniinae

Stenoperla

S. australis S. prasina

The Order Perlaria comprises the stone-flies which are cosmopolitan and possess aquatic nymphal stages. Tillyard (1921) formed the new family Eustheniidae, giving the following characters in his key:—

"Large insects with numerous cross-veins on all parts of the wing, including the anal fan, whose margin forms an unbroken contour with that of the rest of the hindwing. This latter distinguishes the Eustheniidae from all other Perlaria. Larvae with visible gills, which are a series of paired latero-ventral abdominal appendages on segments one to five, or one to six."

In (1923) the same author split this family into three different sub-families all closely allied, and defined the Stenoperlinae as being:

"Insects of large size, slender build, and of green, yellow, brown, or grey coloration. Forewing about five times as long as broad, the costa not dilated basally. Cerci short. Male with short superior appendages and short upturned copulatory hook."

The Stenoperlinae contains two genera each with two species, of which *Stenoperla* is distinguished as being "moderately large insects with a wing expanse of from fifty to seventy millimetres. Antennae from one-half to one-third as long as forewing. Pronotum somewhat heart-shaped, about as wide as long. Costal series of veinlets few and incomplete, there being always a long gap between the humeral veinlet and the next one. Medio-cubital cross-veins in the forewing forming a single row of cellules, only occasionally connected by a cross-bar."

Stenoperla prasina is easily recognised by its large size and by the bright green colouration of the wings.

Habitat.—It is found in all parts of New Zealand, being most abundant in the cold mountain torrents, and occurring less frequently in the shingle rivers of the plains. It is not nearly so numerous as Hudson (1904) states, and is not always found wherever there is running water. Occasionally a yellow variety is found in which, according to Tillyard, the wings are somewhat shorter than in typical specimens.

Type.—In British Museum Collection.

The only other species in this genus so far described is *Stenoperla australis*, which occurs in eastern Australia, but it is probable that other species will be discovered when more extensive collecting and work has been accomplished on this genus.

DISTRIBUTION.

The distribution of the Stenoperlinae is extremely interesting in that it brings out the relationship between Chile, New Zealand, and Australia, as indicated by other distributions. This sub-family occurs in South Chile, the whole of New Zealand and eastern Australia, including South Australia, but excluding Tasmania, and nowhere else in the world. Its absence from Tasmania is probably due to the fact that extensive collecting as yet has not been carried out in this area. *Stenoperla* occurs in eastern Australia and New Zealand, whilst the closely allied genus *Diamphinoa annulata* (Brauer) occurs in Chile, which might be taken as evidence supporting a southern connection between these land masses.

METHODS AND MATERIAL.

Collecting.—Nymphs were collected from a number of different localities described later in the section dealing with Bionomics. They were collected at different times of the year by means of a net of about ten to twelve inches diameter, made of Aertex material supported on a wire frame. This net was placed on the down-stream side of the stone to be lifted, and, as this was performed, quickly brought into position beneath it. By this means all nymphs clinging to the underside of the stone were swept into the net by the force of the current. Living nymphs were transported to the laboratory in glass jars whose stoppers were pierced with holes. These jars were filled with damp moss and fern and all the water poured off. Fresh water was flowed on and then poured off again each day. Nymphs

were kept alive by this means for considerable periods, and, indeed, four overlooked after one field expedition lived in the damp moss for six weeks.

Rearing.—At first nymphs were found difficult to rear, due to variations in temperature and oxygen content, but these two difficulties were finally overcome; firstly, by setting up the cages in a position in the laboratory where very slight change of the temperature of the surrounding atmosphere took place, and, secondly, by using watertight cages with gauze tops and glass fronts. These cages were connected to an aeration system whereby a continuous stream of air was kept passing through the water. Sand and stones were placed on the bottom of the cages, and nymphs were fed on the nymphs of mayflies, *Deleatidium sp.*, and *Coloburiscus sp.*

Material.—Material for fresh dissection was killed in hot water and dissected in Ringer's Solution, while the major portion of dissections was performed on material killed and fixed in five per cent. formalin. For the dissection of very small systems such as the sympathetic nervous, etc., very fine glass needles, made by drawing out glass rods to various shapes and thicknesses, were found indispensable.

Reactions to Light.—Reactions to light were conducted in a wooden box (Pl. 43, Fig. 41) divided into two compartments communicating with one another at the bottom. Each compartment was capable of being rendered dark by means of a lid, and each was connected to the aeration system so that the oxygen content on each side would be approximately the same. By this means the oxygen factor was eliminated. No food, stones, vegetable matter, or anything likely to cause the attraction of the nymphs was placed in the apparatus.

Mounting.—Whole mounts of legs, mouth-parts, tentorium, and wing-buds, after maceration—except the last—were mounted in De Faure's Fluid (Imms 1929). This gave better results than Canada balsam, rendering structures clearer, especially after a day or two. Picro-nigrosin or Fuchsin was used to stain chitinous structures including, besides those mentioned above, the sclerites and genitalia. Wing-buds were mounted by the Comstock-Needham method for tracheation.

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BIONOMICS.

INTRODUCTION.

The following is an account of the preliminary study of bionomics of *Stenoperla prasina.* Thus far investigations have been confined to the nymph, as adults are difficult to obtain alive; the former, however, is both the more interesting and the more important on account of the high specialisation attained in correlation with the aquatic habitat.

HABITAT.

Swiftly flowing streams with a high percentage of oxygen in solution are preferred by the nymphs Field collections made in Canterbury south of Mount Grey, Otago, and Southland have shown that the nymph inhabits the turbulent mountain streams which feed the tributaries of the large rivers, occurring in small numbers along the courses of the latter. In Otago and Southland collections were made in a number of the large rivers along their lower reaches, but no *Stenoperla* was obtained; indeed, these regions are relatively deficient in insect life.

They occur both in the small side branches and in the main courses of these mountain streams, being most plentiful in the former where there are plenty of rock fragments, beneath which the nymphs secrete themselves. Preliminary experiments were made to determine the velocity of such streams at different points, to discover those conditions which prevailed in the region inhabited by the nymphs Difficulty was experienced at this stage in finding a piece of apparatus which would give an accurate measurement of spot velocities, and to eliminate the excess of air which is continually present in the more turbulent torrents. Finally, the following pitot tube was constructed and found to work efficiently.

It consists of two brass or copper tubes 17 inches long, the one one-eighth of an inch in diameter and the other one-sixteenth of an inch in diameter. (Pl. 32, Figs. 1 and 2.) The wider tube is cut off at an angle, which is determined when the instrument is calibrated; the other is bent at right angles so that its opening projects in the same direction as the former (Pl. 32, Fig. 2). These two tubes are enclosed in an outer one which serves merely for protection; the distal portions have two wider tubes sweated on to serve for the insertion of rubber tubing which connects this portion of the apparatus with the head piece. This consists of two glass tubes one-quarter of an inch in diameter and 24 inches in length (Pl. 32, Fig. 1) enclosed in a brass case 1 inch in diameter, having an opening through which readings may be made. To one end of these glass tubes a mouth-piece is connected by means of a Y-piece. Three cocks, one to each limb and the other to the mouth-piece, were used, the reason for the three being given later.

To bring the instrument into operation, the basal portion is placed so that the openings of the tubes face upstream and is held in position by means of a clamp. With the stop-cocks open, water is sucked up until each glass tube and the mouth-piece are filled with water;

the cocks on each arm are then closed to hold the limbs in this condition whilst the mouth-piece is closed; then the former are opened. The whole instrument should be filled with water and *quite free from air.* The cock on the mouth-piece is then cautiously opened until the water runs back in each arm to about half the length of the gauge and is then shut. If now the head oscillates up and down so that readings are difficult, it can be rendered more steady by screwing up the cocks on each arm. The head will then take longer to reach a constant, but when this is attained it remains quite steady, and can readily be measured with a rule. This oscillation of the head was the chief and most difficult factor to overcome, as in other types of pitot tube it oscillates violently.

The difference in height of the two columns is the head (h), and from the following formula:—

$$v = k\sqrt{2\,gh}$$

where k = constant determined on calibration

g = acceleration due to gravity

h = head

the velocity can be determined at any particular point at any given time.

From observations made in this way it was found that around a stone, the region of greatest velocity was before and on top, but the region of lowest was behind and beneath; intermediate velocities were found to the sides, depending on the position of the stone. In some cases, negative velocities were recorded behind stones, but in no case was a region of high velocity found in this position. Clemens (1917), in a more extensive study on *Chirotenetes,* obtained similar results.

Now the nymphs are invariably found beneath the boulders with their heads upstream, where, from the above observations, it is evident that this is the optimum position in turbulent streams. Correlated with the velocity is the dorso-ventral flattening of the body, which, according to Clemens, presents the least surface to the current, and the very efficient adaptations of the legs, to be described later. These structures enable the nymph to hold on and to run across the substratum from boulder to boulder.

The location of the nymphs varies with the type of stream; in the one case it is beneath decaying plant detritus in rills which are abundantly oxygenated, and in the other beneath stones in turbulent streams where all plant detritus may or may not have been swept from the interstices.

Food.

The nymphs feed chiefly on the nymphs of mayflies, *Deleatidium, Coloburiscus, Ameletopsis,* and *Oniscigaster,* but may also prey upon Blepharocerids, other small stoneflies, and even upon other less fortunate fellows of their own species. In one instance it is reported that the nymphs come out at night and actively hunt the substratum. They will not eat dead food, but must have living prey, which is killed and devoured on the spot.

SIZE.

Observations in the field revealed that three sizes occurred, and measurements on such material supported this. The smallest size on the average is about 1 5 cm in length, the intermediate 2·4 cm.; this latter represents the size of the fully grown nymph prior to the appearance of wing-buds; the largest is 3 3 cm. long, this being the maximum size attained by the fully grown last nymphal instar. Since these three sizes are constantly found in the field, the life history is considered to extend over at least two years and probably extends to three.

TEMPERATURE

The *minimum temperature* is below 0° C.; the *optimum temperature* ranges between 6° C. and 14° C., and the *maximum temperature* is 25° C., above which nymphs die very quickly.

RESPIRATION.

The nymphs show decided body movements in relation to respiration. The body is moved up and down in relation to the substratum by means of the legs, the tarsi remaining fixed; by this means the gills are moved to and fro and in consequence are exposed to the maximum amount of water.

LOCOMOTION.

The nymphs actively run about by means of their legs, and if agitated while in still or relatively still water swim by means of lateral undulations of the body assisted at the same time by their legs, which are used as paddles by virtue of their possessing natatory hairs later described.

REACTIONS TO LIGHT.

(Pl. 43, Fig. 41.) The nymphs are decidedly negatively phototactic, and when placed in the apparatus in the lighted compartment rapidly make their way into the darkened one. The last nymphal instar is less markedly negatively phototactic and takes a much longer time to react. The imagines, likewise, are negatively phototactic.

ENEMIES.

The chief enemy of the nymphs is *Archichauliodes dubitatus* (Neuroptera), and trout which possibly also feed on the imago.

PARASITES.

Thus far these number three. The first of these is a Gregarine found in the mesenteron (Plate 32, Fig. 3). It has no epimerite, but has a well-marked protomerite and deuteromerite. Large cysts of this parasite were taken from the hind-gut of the same specimen, a last nymphal instar.

Another unidentified parasite occurs in the mesenteron muscle layers of both nymph and adult, and has been observed in the fat body. It occurs in either muscle layer of the gut and forms a cavity in which it lies and increases in size.

Finally, an unidentified mite has been found on the nymph.

Habits of the Adult.

The adults are crepuscular and are never found very far distant from the streams. Such adults as have been taken were caught about the middle of the day beneath large boulders bordering the streams. Of these, four brachypterous males, all sexually mature, were captured associated with a normal winged female. According to Tillyard (1926) brachypterous males usually associated with normal females occur in other genera.

The adults are all negatively phototactic and immediately secrete themselves beneath stones when placed in the light. They have not been observed to feed, and evidence is given later to support the view that they do not.

Ecology.

A study was made of four particular regions, but as has already been mentioned, collections have been made from Mount Grey to Invercargill, these collections clearly showing that *Stenoperla* occurs to a very much less extent in the lower reaches of the largest rivers, and in many cases is entirely wanting. The four regions mentioned above may be divided into two groups according to the cycle of erosion, one of which may be further subdivided into two according to the origin of the rocks.

1. Early maturity textures of dissection fine.
   (a) Sedimentary Greywackes. Mount Grey.
   (b) Volcanic. Kaituna, Purau.
2. Young river valleys texture of dissection fine.
   Cass-Arthur's Pass Region.

Mount Grey.—In the lower portion of this region the floor of the stream-bed is formed of water-worn pebbles covered with a profuse growth of algae and diatoms, and is inhabited by *Archichauliodes*, Caddis, *Gobiomorphus* (Pisces), and *Hydropsyche*. Here no *Stenoperla* was collected. Passing up towards the source, the stream gradually became more turbulent, the visible algae on the stones decreased, and finally disappeared altogether, whilst the banks were clothed with native bush. Here nymphs were taken associated with *Deleatidium*, Caddis, and *Hydropsyche*.

Kaituna.—The stream in this locality descends a valley of early mature dissection to discharge into Lake Ellesmere. It is turbulent in regions, with falls and pools, in the latter of which plant detritus has accumulated; the stones vary in size from 1 cm. to 1 metre in diameter and are all water-worn.

Temperature.—

14–iii–31	12·0° C.
20–v–31	14·5° C.
7–vi–31	14·0° C.

Association.—*Hydropsyche* sp. and other caddis; *Deleatidium* sp., *Austrosimilium* sp., *Coloburiscus* sp., Chironomids, *Potamopergus* sp., *Helicopsyche* sp., and *Austroperla cyrene.*

Most nymphs were collected in the turbulent portions beneath boulders, but a few were taken in the plant detritus.

PURAU (Pl. 44, Fig. 43).—The Purau stream is a small water-course draining the inner western slopes of the caldera which forms Lyttelton Harbour, and arises high up on Mount Herbert (3014 feet). It runs in a north-westerly direction and discharges into the sea.

Grade.—Coarse sand to large boulders. In its lower reaches the stream bed drops very gently to sea level, and the flow is much reduced in speed.

Association.—Blepharocerids, newly hatched *Deleatidium* sp. (extremely numerous), *Hydrobiosis* sp., *Olinga feredeyi*, *Archichauliodes* sp., *Coloburiscus* sp., *Chironomus* sp., *Potamopergus* sp. Its banks are grassy and the stones in the stream are water-worn and have an algal and diatomaceous growth, and it is the first stream in which *Stenoperla* was collected associated with *Archichauliodes*, which is usually confined to the lower portions, whilst the former frequents the upper. It is evident that a certain amount of overlapping occurs, and that *Stenoperla* is only able to inhabit the lower regions in very small numbers, by virtue of its more active habits, the slower moving *Archichauliodes* nymphs readily devouring such of the former as come within reach of their enormous jaws.

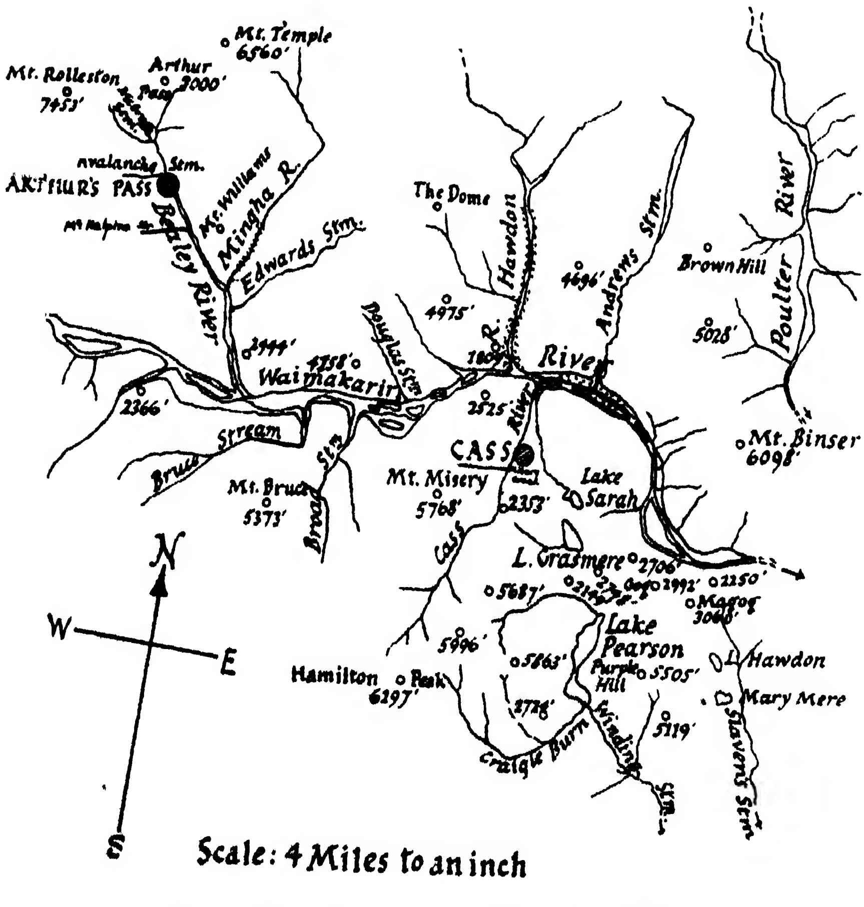

FIG. 1.—Map showing Cass-Arthur's Pass region.

Cass-Arthur's Pass District (Map).—This district comprises the upper watershed of the Waimakariri River and its tributaries, many of the latter of which form large rivers in themselves. The region is situated far back in the Southern Alps and has an average annual rainfall of 50 inches. Thus the tributaries and their branches are subject to severe flooding and rise with great rapidity. Many of the streams are spring-fed, hence their temperature remains constant; in others, however, where the stream is merely a small trickle, the temperature may vary from warm conditions in summer to 2 to 3° C. in winter.

In this region in mid-winter the snowline has descended to somewhere about the 2000ft. level, and falls are frozen, while the ground is frozen to a depth of many inches and the stones in streams are covered with ice to a depth of 3 to 4 inches on their upper surfaces. The streams are all turbulent mountain torrents carving out valleys and gorges in folded and faulted greywacke and phyllite. The Cass region itself is a glaciated valley, the terminal moraine of which retains three lakes—Lakes Sarah, Grasmere, and Pearson—into the latter of which discharges Ribbonwood Creek, to be described more fully later.

Misery Creek (Pl. 44, Figs. 44 and 45).—It is a typical spring-fed mountain torrent draining a sub-alpine fell-field, and descends along part of its course by a long series of cataracts to discharge into a swamp; thence it drains into the Cass.

Grade.—Small stones to large boulders.

Temperature.—

24–x–30	6 0° C.
25–x–30	6·0° C.
30–xii–30	6 5° C.
27–viii–31	6 5° C.
18–ii–32	6·5° C.

Association.—*Zealandoperla* sp., *Deleatidium* sp., Blepharocerids, *Austroperla cyrene, Ameletus* sp., Caddis, *Austrosimulium* sp.

Plant.—Very little algae, chiefly diatoms. Beech on banks (*Nothofagus cliffortioides*).

It is interesting to note that a certain portion of the stream changed its course twice, finally returning to its old bed. Its fauna, however, remained constant. *Stenoperla* occurs only in its upper reaches, at an altitude of 2,750ft.

Ribbonwood Creek (Pl. 43, Fig. 42).—This is also a typical mountain torrent draining a similar but smaller basin to the Cass River at the back of Mount Baldy, emptying into Lake Pearson at its northerly end. About two and a-half miles from Lake Pearson, at an altitude of 2,750ft., there is a very small side trickle about 50ft. long arising from a scree. Most work has been accomplished on this stream, since it is very thickly populated and very interesting from many aspects.

Grade.—Coarse sand to large boulders, plant detritus abundant.

Temperature.—

28–viii–31	.. .. ..	7 0° C.
17–ii–32	.. .. ..	8 5° C. (cold spell)
26–v–32	.. .. ..	7 5° C.

Association.—(a) Animal: ***Deleatidium vernale, Ameletus*** sp., *Tipula* sp., *Olinga feredeyi, Austroperla cyrene, Zealandobius* sp., *Chironomus* sp., *Austrosimulium* sp., *Amoeba* sp., *Paramoecium* sp., and Rotifers.

(b) *Plant:* The stream could be divided into three regions according to the Cryptogams.

1. *Upper*, about 15ft. in length.

Green algae.
- *Spirogyra* sp.
- *Zygnema* sp.
- *Vaucheria* sp.

Blue-green algae.
- *Oscillatoria* sp.
- *Auabena* sp.

Desmids.
- *Staurastrum* (2 spp.)
- *Closterium* sp.
- *Cosmarium* sp.

Diatoms.
- *Navicula* (3 spp.)
- *Cymbella* sp.
- *Tabellaria constrictum*
- *Melosira* sp. (predominant)

2. *Middle*, about 20ft. in length.

Diatoms.
- *Melosira* sp.
- *Pinnularia* sp.

Green algae.
- *Spirogyra* sp.

3. *Lower*, about 25ft. in length. The cryptogam flora resembles the upper region.

Now the interesting fact about this is that the upper and lower regions are plentifully supplied with plant food, especially *Melosira* sp., and that this genus enters into and forms an important part in the food relations of the herring in the North Sea. An analysis of the animal fauna shows that *Deleatidium* sp. and *Ameletus* sp. were abundant in the upper and lower reaches, but were absent from the middle, whilst the large *Tipula* sp. was very plentiful in this latter. It is known that mayflies eat diatoms and an analysis of a *Stenoperla* nymph in the crop region revealed fragments of mayflies of the above two genera, together with an enormous amount of plant food, which consisted chiefly of *Melosira* sp. together with filamentous algae. Now, the stoneflies feed on the mayflies, which in turn depend on the algae for their food, and it has already been shown that the middle portion was deficient in diatoms, which would explain the absence of mayflies and stoneflies. On the other hand, over two hundred nymphs were taken out of the upper position where *Melosira* sp. was very abundant.

NYMPH.

External Anatomy.

The Nymph (Pl. 33, Fig. 6) of *Stenoperla* is of the campodeiform type, about 2 4 cm. in length just prior to the visible appearance of the wing-buds. The entire body is flattened dorso-ventrally, varying in colour from bright green to a reddish brown, depending on the dominant colour of the habitat. The ventral surface varies from very light green to whitish green; whilst the intersegmentalia vary from this latter colour to pink.

The Head (Pl. 33, Figs. 7 and 8) is flattened dorso-ventrally, slightly convex above, about as long as broad, with a distinct Y-shaped epicranial suture, the arms of which extend to the base at the antennae. The compound eyes are large, with numerous ommatidia, reddish brown, being on the lateral aspect of the epicranium. There are three ocelli situated between the eyes. On either side of the median ocellus, and anteriorly on the frons, are two small but distinct depressions, the invaginations of the dorsal arms of the tentorium, and two larger ones whose function is unknown, lie in the front. The frons is a large plate twice as broad as long, separated from the clypeus by a distinct clypeal-suture. It bears the pits mentioned above and the ocelli; the vertex is not differentiated as a separate sclerite. The gena extends laterally and ventrally to form the lateral and latero-ventral aspect of the head, and meets the mentum and gula on the ventral surface. It bears on its postero-lateral border a small tuft of fine setae (P. 33, Figs. 7 and 8). The clypeus is three times as broad as long, undivided, and has two small depressions lying in front of those on the frons. The breadth of the labrum is four times the length, and is separated from the clypeus by a distinct clypeo-labral suture. The antennae are long, multi-articulate, filiform appendages in which the scape is the longest and the pedicle a little shorter than the former; there are numerous other small segments. The head articulates with the thorax by a very short intersegmental region.

The Tentorium (Pl. 32, Fig. 4) is made up of the normal elements. There is a body from which a pair of arms pass dorsally forwards—the anterior arms—to the lateral clypeo-frontal region, where the gena joins these two latter. They give rise to the condyle on which the jaws articulate, and thus support these powerful organs. Dorsally, and mid-way along the anterior arm, the dorsal arm is given off to the head, and is visible externally in the two pits on the frons mentioned above. Posteriorly the posterior arms pass back to the occiput. The body of the tentorium descends ventrally and joins the gena of either side. It supports the oesophagus, protects the suboesophageal ganglion, and serves for the insertion of muscles.

The Thorax (Pl. 33, Fig. 6).—The prothoracic tergum is oval, twice as broad as long; the meso-thoracic similar in shape and half as wide again as long, whilst the meta-thoracic tergum is similar to the latter. All these tergites show the primitive undivided condition.

The Pleurites (Pl. 32, Fig. 5). (Snodgrass 1909.) There is an undivided anteriorly placed episternum and a slender posterior epimeron, the latter being separated from the former by the pleural suture. There is no pre-episternum. The remaining two sclerites are latero-sternites according to Imms (1925). The more posterior sclerite is sickle-shaped, and articulates with the episternum, epimeron, and the coxa—the trochantin; whilst the more anterior one forms a large sclerite lying between the episternum and the sternum and forms the "ante-coxal plate," which is homologised with a similar structure found in the cockroach and quoted by Balfour-Browne (1932). That it is not pre-episternum is concluded from the fact that, were it such, it would have to slip downwards and backwards beneath the episternum to reach its present position, a condition which seems most improbable. It is not presternum, as will be seen from Pl. 35, Fig. 14, where it is shown that this sclerite is small, does not reach the lateral margins of the ventral surface, and, furthermore, lies anterior to the sclerite in question. On the above grounds it is concluded that it is a latero-sternite and is homologous with the ante-coxal plate of the cockroach.

The Sternites (Pl. 35, Fig. 14).—The presternum is composed of a single, large, oval plate formed by the fusion of sternum and sternellum; evidence for this is seen in that posteriorly and laterally, a pair of furcae arise, thus identifying the sternellum (Imms, terminology); the anterior portion of the plate must then be composed of the verasternite of Martin (1916) and the sternum of Imms (1925). Now, according to Martin, the thorax is made up of five different subdivisions, and although direct evidence is at present lacking, the presternum and post-sternellum are either lost or have become fused with the sternum and sternellum. The furcae mentioned above are united at their distal ends with the pleural arms, thus forming a very strong internal connection between pleuron and sternum. Externally, two pits (Pl. 35, Fig. 15) lying between the legs of each segment are visible; these are the invaginations which give rise to the furcae. They correspond to the pits observed by Newport in *Pteronarcys* (1851).

Posterior to the presternum is a very small spinasternite, largely made up of the spina and serving for muscle insertion. The spina in *Stenoperla* is homologised with the thoracic pits of the cockroach (Miall and Denny 1886), since it is situated in a similar position and resembles them in appearance. It is thus the homologue of the spina in the Orthoptera.

The Mesosternum has a small oval sclerite, the presternum, situated just posterior to the spinasternite of the prothorax. Behind this lies a large plate composed of sternum, sternellum, and possibly post-sternellum; from the lateral aspect of which arise a pair of furcae similar in every respect to the preceding. Posterior to this sclerite there is another small spinasternite with its spina.

The Metasternum is made up of two plates, the anterior of which forms the presternum and is oval in shape. The posterior plate is composed of the same sclerites as that in the mesothorax,

but again, as in the case of the two preceding regions, evidence is lacking as to whether the post-sternellum is fused with the plate or is absent. Two furcae arise in a similar position and resemble the preceding ones in every respect. There is no spinasternite present, but if Martin's statement that the spinasternite probably belongs to the segment in front is correct, then this is to be expected. Again, as would be expected, and supporting this view, no spinasternite is found in the anterior region of the prothorax.

Mouth Parts.

The Labrum (Pl. 33, Fig 7, and Pl. 34, Fig. 9) is an undivided sclerite four times as broad as long, having on its anterior median border a broad, shallow indentation. Its whole outer edge is provided with numerous macrotrichia.

The Epipharynx is formed of a membrane closely adherent to the labrum on its ventral surface, and is densely clothed with macro- and microtrichia. The macrotrichia are disposed on the lateral regions, and are probably of a tactile nature. There is no sign of differentiation.

The Mandibles (Pl. 33, Fig. 8, and Pl. 34, Fig. 10) are very strong and undivided, with a number of small, sharp, heavily chitinised teeth; no molar region; they are adapted for seizing, cutting, and tearing their prey to pieces. They articulate with the head by a condyle and ginglymus. On their inner aspect a large chitinous plate, the adductor apodême, is attached to the powerful adductor muscles and represents the chitinised tendon. This plate lies ventral to the anterior and dorsal arms of the tentorium.

The Maxilla (Pl. 33, Fig. 8, and Pl. 34, Fig. 11) has a cardo divided into two, a proximal region or basicardo, and a distal region or disticardo. The disticardo is attached to a long, slender, undivided eustipes, which on its outer lateral aspect gives off a five segmented palp. No micromere as described by Crampton (1923) in *Eusthenia* was observed. The lacinia is well developed, and bears at its distal end two heavily chitinised teeth; the galea is divided into two, a proximal smaller region or basigalea, and a longer distal region or distigalea, the latter of which is not chitinised, but is fleshy.

The Labium (Pl. 33, Fig. 8, and Pl. 34, Fig. 12).—The mentum is a large, well-developed plate two-thirds of the length of the labium, and forms the floor of the head except for a very small posterior gular region. The prementum is partially divided, giving rise on either side to a palpiger, from which a three-segmented palp arises. The ligula is well-developed, having both glossae and paraglossae present, of which the latter are the larger.

The Hypopharynx (Pl. 34, Fig. 13) lies on the upper surface of the labium and consists of a single undivided plate, whose median anterior margin is produced forwards to form an obtuse angle. From the sides of this plate arise the bilobed superlinguae, the anterior lobe of which bears large macrotrichia probably of a tactile nature. From the median posterior margin a process continues backwards,

bifurcating into two arms which support the salivary duct of each side; on to this median prolongation the united ducts run forwards to open on the hypopharynx on the side apposed to the labium.

Thoracic Appendages.

The Legs consist of seven segments as follows: A small undivided coxa articulates with the trochantin, and articulates on its distal border with a small undivided trochanter. This is followed by a long stout femur and tibia, the latter bearing a terminal, heavily chitinised spur; and, finally, by a three-segmented tarsus of which the distitarsus is the longest, bearing a pair of very strong terminal ungues. The other two segments are short and equal in size; there is no empodium, nor are there any pulvilli. In life the tarsus is brown, whilst that of the other segments is green.

The femur and tibia bear on their postero-lateral borders long natatory hairs, used by the nymph to assist the lateral undulations of the body during swimming.

The basi- and medio-tarsal segments bear on their ventral surface two rows of very stout bristles (Pl. 35, Fig. 16), which are situated around the margins of two depressions, one on each segment, and these, together with the terminal ungues and tibial spur, form a very efficient crampon by means of which the nymph is enabled to hold on against very swift currents. That the structure is purely an aquatic adaptation is indicated by the fact that it is lost in the imago and is replaced by two pads.

The Abdomen (Pl. 33, Fig. 6) is ten-segmented, with the first segment reduced in size. On either side of the mid-dorsal line, one pair to each segment, are two rows of small round areas forming a constant pattern and lighter than the general body-colour. On the last segment there are three, the odd one being situated posteriorly on the midventral line. Five pairs of white, segmented, tracheal gills are present on the first five abdominal segments. The abdomen bears on the last segment a pair of filiform, multi-articulate cerci which are about one-third of the total body length, green on the proximal and brown on the distal segments.

INTERNAL ANATOMY.

Alimentary System (Pl. 40, Fig. 33).—The alimentary canal can be divided into the following regions:—

1. Foregut (Stomadoeum)	(a) Mouth
	(b) Oesophagus
	(c) Crop
	(d) Gizzard
2. Mesenteron	
3. Hindgut (Proctodaeum)	(a) Ileum
	(b) Colon
	(c) Rectum

Foregut.

The Mouth is bounded above by the labrum, laterally by the mandibles and maxillae, and ventrally by the hypopharynx and labium. This leads into a muscular—

Oesophagus, which runs the entire length of the head ventral to the brain and dorsal to the body of the tentorium, behind which the oesophagus bends downwards and passes along the floor of the head, giving off radial muscles to the roof, sides, and floor as it goes. In the region of the cervicum the oesophagus constricts and passes backwards into the prothorax, where it gradually expands out into a very thin-walled sac, the—

Crop, which extends back to the middle of the metathoracic segment. When empty or only partially filled with food the walls are thrown into longitudinal folds. Posteriorly it narrows and passes into the—

Gizzard, which is very difficult to distinguish externally except in those cases where the foregut is filled with dark food material, when the greater thickness of its walls render it visible.

The Mesenteron follows the gizzard and joins the latter at the junction between the metathorax and first abdominal segment. It is a long straight tube extending back to the sixth abdominal segment, narrowing towards its central region, but widening again posteriorly. At its anterior end two very short, forwardly directed caeca are given off laterally. Its posterior half is pigmented with cylindrical pigment granules.

The Hind-gut extends from the sixth abdominal segment backwards, and, at its junction with the mesenteron, gives off a large number of Malpighian tubules (50 to 60), which run forwards to find attachment on the posterior region of the gizzard. The anterior portion of the hindgut dilates to form the *ileum,* which, in turn, constricts posteriorly to pass into another dilation, the *colon-rectum,* extending to the anus, which discharges on the tenth segment between the cerci. The posterior region of the rectum, as in the oesophagus, gives off radial muscles and constricts to form a sphincter.

Glandular and Excretory Structures of Alimentary Canal.

The Salivary Glands (Pl. 40, Fig. 33) consist of a pair of racemose, whitish bodies, deeply embedded in and closely resembling the fat-body. There are two pairs, one on either side of the prothorax. The more posterior gland lies dorso-laterally on the crop, to which it is closely adherent, the more anterior is situated near the cervicum and is deeply embedded in the fat-body, from which it is difficult to separate. Each gland consists of a number of acini opening into a very slender salivary duct, the more posterior duct passing forwards to be met by a similar duct from the anterior gland. The common duct passes forward mid-laterally along the oesophagus till near the mouth, where it descends and meets its fellow from the opposite side mid-ventrally. The common duct so formed runs forward on the horn of the hypopharynx to open on this latter

structure on the side apposed to the labium (Pl. 34, Fig. 13). There is no salivary reservoir, and the main ducts are provided with taenidia.

The Malpighian Tubules (Pl. 40, Fig. 33).—These vary from 50 to 60 in number, are long, thin tubules about 1 cm. long, and are arranged in a double row around the mesenteron, each opening into the latter by means of a separate opening situated on the apex of a small papilla. (Histological evidence for this will be presented in a later paper.) For about two-thirds of their distal length the lumen is clear and well-defined, but in the proximal third becomes reduced in size by the approximation of the cells and the accumulation of solid urates. The distal portion is lined internally by a darkened membrane, the *striated border* (Wigglesworth), which, according to Wigglesworth (1931), cannot be separated into its constituent striae. This border becomes more evident in the proximal region, and its constituent elements become discernible. In a freshly killed specimen each tubule exhibits a slow serpentine movement. All are well provided with trachea, the tracheoles of which run along their length. The distal region of each tubule is produced into a delicate *terminal filament* by means of which each is attached to the gizzard; thus far no reference to this has been found, and Wigglesworth does not appear to have observed anything of this nature in the Reduviid bug. A similar condition has been observed in another stonefly nymph.

The Fat-body consists of two pairs of organs which attain their maximum size in the abdomen, but extend forwards into the thorax and head. The dorsal pair lie dorso-laterally and are situated in the pericardium; they constitute the pericardial fat-body. The ventral pair, the adipose fat-body, occupy a ventro-lateral position, but lie beneath the gut and gonads.

The Nervous System.

The nervous system of *Stenoperla* is divided into the following parts:—

1. The brain situated in the head above the oesophagus.
2. The sympathetic nervous system.
3. The sub-oesophageal ganglion.
4. The ventral nerve cord.

The Brain (Pl. 36, Figs. 20 and 21, Pl. 40, Fig. 34) is a large mass of nervous tissue situated in the head above the oesophagus, and extends over the greater part of this region between the compound eyes. It is convex above and concave beneath, with the anterior and dorsal arms of the tentorium passing between the antennary and optic nerves, and is wider than long. Three parts are distinguishable:—

1. The Proterocerebrum.
2. The Deuterocerebrum.
3. The Triterocerebrum.

To understand the relationship of these three, the one to the other, it is necessary to investigate the condition of the segments which originally gave rise to them. Primitively, the mouth was

ventral in position, but has moved forwards to take up a position at the extreme anterior portion of the body, with the result that the clypeus and labrum have been pushed up and lie dorsal to it. Similarly, the deutero- and triterocerebrum have moved forwards, the former upwards over the oesophagus and through 90°, taking the triterocerebrum with it; the proterocerebrum lies behind these and has rotated through 90°. The triterocerebrum now lies on either side of the oesophagus and *not* above it, hence the deuterocerebrum has come to overlie the former

The *Proterocerebrum* consists of a pair of lateral lobes united along their middle line, and forms the greatest and posterior region of the brain. Each lobe gives off a nerve on either side to the lateral ocellus of its side, and anteriorly between the junction of the protero- and deuterocerebrum the nerve to the median ocellus is given off. Attached to the proterocerebrum on either side is a large optic lobe, wider than it is long, directed laterally. It gives rise to the optic nerve Posteriorly and ventrally the proterocerebrum gives off the hinder region of the sympathetic nervous system, but it is possible that this may retain an internal connection with the triterocerebrum.

The Deuterocerebrum consists of two well-developed lobes, one on either side directed latero-anteriorly, and connected to one another by a piece of nervous tissue forming the dorsal lobe of the brain. Each lobe gives off a double antennary nerve to the antenna of its side, the more anterior nerve being the larger.

The Triterocerebrum lies ventrally to the deuterocerebrum on either side of the oesophagus. Each trito-cerebral lobe is connected with its fellow by a post-oesophageal commissure, which descends from each lobe and encompasses the oesophagus. It also gives rise to the two large para-oesophageal commissures which run downwards and backwards to the suboesophageal ganglion, and to the labro-frontal nerves which form the root of the frontal ganglion

The Sympathetic Nervous System.

The sympathetic nervous system (Pl 36, Figs 20 and 21, Pl. 40, Fig 34) resembles that of the saltatorial Orthoptera, in that there is a paired stomatogastric nerve, each with its own stomachic ganglion. A small triangular frontal ganglion lies in front of the brain, giving off anteriorly a nerve to the clypeus. Laterally, two nerves run latero-anteriorly and arch backwards to find connection with the labro-frontal nerves of the triterocerebrum Each of these nerves gives off another pair which run forwards to innervate the mouth parts. Posteriorly the frontal ganglion gives off the recurrent nerve, which runs backwards beneath the brain to join a mass of nervous tissue representing the fused oesophageal and hypocerebral ganglia. It is probable that the corpora allata are included in this fused mass, as they are not represented elsewhere. A pair of bodies, at first thought to be these were afterwards revealed to be stomachic ganglia. From the antero-lateral aspect this mass gives off two connectives to the brain; postero-laterally on either side there arises a stomatogastric nerve, which descends to a medio-lateral position on the oesophagus and runs backwards to the cervicum, where it gives off a small whitish

body, the stomachic ganglion. Thence it runs backwards parallel to the salivary duct, finally arborising on the anterior caeca of the mid-gut (Pl. 40, Fig. 33). The ventral system has not been traced, but paired transverse nerves have been observed associated with the ganglia of the ventral nervous system.

The Ventral Nervous System (Pl. 37, Fig. 22).

The ventral nervous system consists of twelve ganglia; a sub-oesophageal, three thoracic, and eight abdominal, all connected by a double nerve cord. The abdominal ganglia all clearly exhibit a double nature.

The Suboesophageal Ganglion is a large, well-developed ganglion lying beneath the oesophagus under the proterocerebrum. It lies on the mentum and is protected dorsally by the body of the tentorium; anteriorly, it gives off nerves to the mandibles, maxillae, and labium, and is connected to the triterocerebrum by the para-oesophageal connectives. It narrows posteriorly and gives off the paired ventral nerve cord.

The Thoracic Ganglia are three in number, each lying in a median ventral position in its segment; all are equal in size. Each gives off a pair of large crural nerves to the legs, and smaller ones to the muscles. They are connected the one to the other and to the suboesophageal ganglion by the paired nerve cord.

The Abdominal Ganglia are clearly divided into right and left halves, and, as before, are connected by a double nerve cord. The first abdominal ganglion lies in the metathorax immediately behind the metathoracic ganglion, and has migrated forwards, but is not fused with the latter. A similar condition is found in dragonflies in some of which this ganglion has actually fused with the thoracic. It gives off a pair of nerves backward to innervate the first abdominal segment.

The remaining seven ganglia lie in segments two to seven. From the anterior portion of the second ganglion a pair of nerves pass outwards and innervate the muscles, etc., of that segment; segment three is innervated by a pair of nerves arising from the connectives anterior to its ganglion, whilst posteriorly to this latter another pair of nerves arise to innervate segment four. Postero-laterally from the fourth ganglion a pair of nerves pass out and innervate segment five, whilst the fifth ganglion innervates segment six by a pair of nerves exhibiting double roots. ganglion six innervates the posterior region of segment six and the anterior of segment seven; the seventh ganglion lies in the intersegmental region between segments six and seven, and gives off a pair of long nerves which pass back to segment eight, innervating the major portion of segment seven as they go. The eighth and last ganglion is larger than the preceding ganglia, and gives off posteriorly a pair of long nerves which pass back into the cerci, innervating segments nine and ten as they pass.

The Reproductive System.—This resembles that of the adult described later; it appears very early in nymphal life.

The Circulatory System.

The heart lies dorsally in the abdomen in segments one to nine. It is a long, delicate tube consisting of ten chambers separated from one another by constrictions, which correspond in position to the intersegmental regions. Anteriorly it continues forwards as a fine aorta to the head, ending beneath the brain. Laterally each chamber opens into the pericardial sinus by paired ostia, and each gives off on its lateroventral aspect two pairs of alary muscles which are attached on either side to the anterior and posterior regions of their segment.

The heart is enclosed in a space, the pericardial sinus, bounded above by the tergum and beneath by the diaphragm; lying in this sinus and on either side of the heart is the pericardial fat body. So far the muscles have not been seen to display striations.

The Respiratory System.

The tracheae (Pl. 37, Fig. 23) consists of a pair of longitudinal, lateral trunks extending backwards from the prothorax. Anteriorly each trunk bifurcates and supplies the head. There are five tracheal gills on either side of the first five abdominal segments.

The Prothorax and Head.—In the region of the prothorax the longitudinal trunk bifurcates into a dorsal and ventral trachea, the latter of which runs practically straight forwards, sending off a large branch to the legs and smaller branches to the cervicum and ventral muscles of the head, bifurcating at its anterior extremity to send one branch to the ventral mouth parts, the other up to the antenna. The dorsal branch runs straight forwards to the cervicum, sending off smaller branches to the muscles in this region, it then curves laterally following the contour of the head, giving off numerous trachea to the muscles, eyes, etc. Anteriorly, beyond the eyes, it curves inwards, giving off two small branches to the antenna, and finally arborises on the clypeus. No commissural connection with its fellow on the opposite side has been traced, any such connection taking place through the tracheoles (cf. adult).

The Meso- and Meta-thorax.—In this region the trunk is single and curves inwards towards the middle of each segment and outwards towards the intersegmental portion. The anterior region of the trunk in each segment gives off a branch laterally to the legs, this latter joining a similar branch from the posterior region. In this way the typical Y-shaped tracheae to the legs as figured by Comstock (1918) is formed. The posterior, metathoracic leg branch receives a trachea from the first abdominal gill.

The Abdomen.—Between segments two to six the main longitudinal trunk curves inwards towards the middle and outwards towards the intersegmental region. The tracheae of abdominal segments two to five are all similar, so a typical segment will be described. In segment two, however, the first branch is a large one running inwards to the gonads; this is not present in the other four. Externally, in the anterior region of each segment, the trunk receives a trachea from the gill; from this branch three others are given off, the largest of which passes inwards and arborises on the gut, joining

its fellow from the other side by tracheoles only (cf. adult); no true commissures are present. The other two branches are smaller and arborise on the muscles and fat body.

From the posterior region of segment five the trunk gives off a large branch internally to the malpighian tubules, and externally just in front of this a small branch to the fat body. In segments six and seven the trunk is much straighter and gives off ventrally a large branch which curves round internally to arborise on the posterior region of the midgut; numerous small branches pass from the trunk to the fat-body and muscles. Between segments seven and eight the main trunk turns outwards, and at this point gives off a large branch internally to supply the whole of the hind-gut. After passing outwards for a short distance, the trunk turns and runs straight backwards to segment ten, bifurcates, and finally passes into the cercus. As it passes, it sends off branches to the fat-body and muscles in segments eight, nine, and ten.

Here and there along the main lateral trunk and on the leg trunks there are white opaque collars.

EXTERNAL AND INTERNAL ANATOMY LAST NYMPHAL INSTAR.

The Last Nymphal Instar (Pl. 38, Fig. 25) resembles the nymph in every respect, except that its average length is about 3·3 cm. and that external wing-buds are present. Its internal anatomy reveals similar organs. The gonads, however, are mature, but will be dealt with under the imago.

The Respiratory System.

The respiratory system very closely resembles that of the nymph, but differs in two respects. The first of these is that the longitudinal trunk in the prothorax soon after the junction of the dorsal and ventral head trunks, gives off a short spiracular branch laterally to the first thoracic spiracle, which is simple, has a small atrium, and is closed. It is situated on the intersegmental region between pro- and mesothorax. Posteriorly in a similar position between meso- and metathorax, the trunk gives off another spiracular branch to the second thoracic spiracle, which is associated with the posterior trunk to the meta-thoracic leg. At this stage no abdominal spiracles are visible nor are any branches to be seen coming off the main longitudinal trunk; stigmatic cords, however, are traceable between the latter and the sides of the body, but only in freshly killed insects.

The second difference is the presence of wing-pads, which, at this stage, have reached their maximum development as such. These, of course, necessarily have special tracheae associated with them (Pl. 35, Fig. 17). The basal connections of the wing-pad tracheae very closely resemble the typical condition as figured by Comstock (1918), and approximate nearer the generalised condition than *Pteronarcys,* where these connections are complicated by the presence of thoracic gills. The typical Y-shaped leg tracheae are present, each arm derived from its corresponding spiracular trunk, of which the

first contributes one branch to the mesothoracic leg, the second one to this appendage and a posterior branch to the metathoracic leg; whilst the last branch of this latter is derived from the trunk to the first tracheal gill. The posterior stem of the first spiracular trunk gives off a branch to the forewing-pad, the costo-radial, which supplies the following veins:—C. Sc. R. and M. together with their cross-veins.

The anterior stem of the second spiracular trunk gives off the cubito-anal trachea to the forewing-pad, and supplies the Cu and A. veins of this structure. In this way the wing-pad receives tracheae from two sources, each in direct communication with a spiracle, and hence is assured of a rich oxygen supply.

In a like manner the hindwing-pad is supplied from two sources, the costo-radial arising from the posterior stem of the second spiracular trunk, and the cubito-anal from the posterior leg stem which arises from the trunk to the first tracheal gill.

As has been stated by Comstock (1918), etc., there is no connection between the radio-costal and cubito-anal tracheae, and the median is still in the primitive condition attached to the former. There is no fusion of the two wing tracheae as found by Tillyard (1917) in Dragonflies, where he states that this condition is the combined result of three interacting forces, one of which being that of relying almost wholly on an oxygen supply coming from the anal end of the alar trunk, owing to the larval gills being situated in this region. Another authority has disputed this point, and it must be stated here that, on the one hand, no support for Tillyard's view can be deduced from the condition of the alar trunks, whilst, on the other, there is the reduction of the costal vein which Tillyard uses to support his theory. This latter vein is lost in the adult, resembling the condition Tillyard found in Dragonflies.

The Wing-Pads

These are about 0 3 cm. in length, lie with their dorsal surfaces uppermost, and project postero-laterally on the tergum.

The Forewing Pad (Pl. 38, Fig 26) has a thick margin well provided with large, stout macrotrichia, and shows quite clearly the fusion of the veins at their bases to form the costo-radial and cubito-anal tracheae, which according to Tillyard (1921) are characteristic of the order as a whole.

The costo-radial trachea on entering the wing-pad splits into three, the anterior branch forming Sc. which runs two-thirds of the length of the pad where it bifurcates into $Sc._1$ and $Sc._2$, the latter of which bends down and almost touches R, or else fuses with it for a short distance, afterwards curving back to the margin of the wing. Just after Sc. leaves the costo-radial a very small costa, which ends before the margin is reached, may or may not be given off. The humeral veinlet is the next branch and is constant in position; following the humeral are a variable number, usually 3 to 4, of cross-veins across the costal space between Sc. and the margin. These are provided with macrotrichia, and there is always a large

space between the first of these and the humeral veinlet. The second branch constitutes R, which runs some distance before branching into a straight, unbranched R_1, and into Rs. This latter branches into R_{2+3} and R_{4+5}, the former again bifurcating into R_2 and R_3. The third branch of the costo-radial is M, which runs some distance before bifurcating into M_{1+2} and M_{3+4}.

A small cross-vein between M and Cu_1 is regarded by Tillyard (1919), as M_5 a basal *concave* vein connecting M with Cu_1, based on the study of the fossil *Belmontia.* It is a characteristic feature of the orders forming the Panorpoid complex. In 1925, after further study, he decided that it was merely a *convex* strut which has secondarily developed providing rigidity to the base of Cu_1.

In 1921, this author figures the tracheation of *Stenoperla prasina,* but shows no trachea between M and Cu_1. In 1923, he figures the venation, naming M_5 as a small cross-vein between M and Cu_1, but gives no reason for doing so. Now this author (1919) also holds that only in special cases do cross-veins bear macrotrichia and that these are more characteristic of main-veins. An examination of the wing-pads and venation by the present author revealed the fact that macrotrichia occur on many cross-veins, especially those between M and Cu_1, including Tillyard's M_5, and between Cu_1 and Cu_2. A similar condition was found to exist in the venation of *Austroperla cyrene* and two species of *Zealandoperla.*

Now, main-veins are preceded by tracheae except in orders where the venation is highly specialised as in Hymenoptera, Mecoptera, Diptera, and Trichoptera, so that if these veins possess tracheae in the wing-pads we might expect them to be rudiments of the archedictyon and so explain the anomaly. If not, then they must be merely cross-veins, and the presence or absence of macrotrichia is not an infallible criterion for main-veins.

The present author examined a large number of wing-pads of *S. prasina* and found that not one of these veins, including Tillyard's M_5, is preceded by tracheae (Pl. 35, Fig. 18). The wing-pads of *Zealandoperla* sp. and *Austroperla cyrene* were also examined, and again no tracheae were found. From these facts it is concluded that in stone-flies M is primitively four-branched.

Again, Comstock's M is a concave vein, and hence must be homologous with Lameere's (1922) MP, which is primitively four-branched. MA likewise is four-branched and, being the anterior branch of M, is convex. According to both these authors then, MP is four-branched, and according to Lameere so also is MA, and as stone-flies are primitive, one would expect a similar condition to exist in this order.

Sections of the wings of *S. prasina* and *Megaleptoperla grandis* were cut, revealing the fact that M was convex, hence it must be homologous with Lameere's MA and not with Comstock's M. After studying the Proto-perlaria, Tillyard (1928) found that MP was already becoming obsolete basally, and that in true Perlaria has entirely disappeared. This it is seen is in agreement with the condition in recent forms and resembles the condition in Odonata.

From the foregoing it is concluded that M in stone-flies is primitively four-branched as postulated by Lameere and Comstock; that it is homologous with Lameere's MA; and that MP is lost entirely in existing forms.

The cubito-anal splits into three branches, the first of which is the cubital. This, shortly after leaving the main trachea, bifurcates into Cu_1 and Cu_2, the former developing a variable number of accessory veins. The second branch is 1A, a straight, unbranched vein, whilst the third by bifurcation gives rise to 2A.

The Hindwing-pad (Pl. 38, Fig. 27) closely resembles the forewing, but differs from that figured by Tillyard (1921), in that the costo-radial is always only *two* branched and not three. A large number of wing-pads have been examined, but this feature appears to be constant. A second difference lies in that M is fused basally for a short distance with Rs as found in the venation. This again is in disagreement with Comstock (1918), who gives as a constant feature the fact that Rs is a branch of R and that it is not switched over to M in the nymphs. This can now no longer be regarded as a true constant, since it is variable in *Stenoperla.*

The costa is a small and weak vein and does not reach the margin of the wing. R is unbranched, Rs divides into R_2, R_3, and R_{4+5}, but M, as stated above, is fused with R and sometimes with Rs for a short distance. M bifurcates into M_{1+2} and M_{3+4}; Cu divides into Cu_1 and Cu_2, but the former has no accessory veins; 1A is unbranched, this feature being constant throughout, and joins the third branch of the cubito-anal which curves round forming a loop from which 2A and 3A and their accessory veins arise, the latter of which are variable in number.

EXTERNAL ANATOMY OF IMAGO.

The imago (Pl. 39, Fig. 28) varies in size, but is on the average about 3·3 cm. in length, and in general shape and appearance resembles the nymph. It is a very swift runner, but a poor flier, is olive green in colour, and is covered with a pubescence of hairs which prevents it from becoming wet when in contact with water. When at rest, the wings are folded flat over the back, the right wing over the left in both cases, so that only the basal portion of the left forewing is visible.

The Head.

This is similar in every respect to that of the nymph, showing the same sclerites and arrangement, but is attached directly to the thorax, the cervicum being reduced.

The Mouth Parts.

These resemble the nymphal structures, but are reduced in size. The mandibles are less heavily chitinised than those of the nymph. All parts exhibit the full number of sclerites. The two lobes of the hypopharynx have lost their suture and appear as one structure.

The Thorax.

The thorax differs only in the distal extremities of its appendages, the legs, in that the meso- and metathorax bear wings, and that the thoracic spiracles are now open. The tibia (Pl. 35, Fig. 19) bears a tibial spur, but the aquatic adaptations of the nymph are now lost and replaced by tarsal pads, and the distitarsus has developed an empodium. The terminal ungues persist, but there are no pulvilli.

The Abdomen.

The only difference in this region is the development of the external genitalia. The five abdominal gills persist as withered appendages, but are still provided with tracheae from the main longitudinal trunks. Newport (1851) described gills as being present on the thoracic segments of *Pteronarcys,* and demonstrates that in the adult the sacs with which the tracheae communicate are provided with trachea from the main longitudinal trunk, and states that they are functional. Similarly it is possible that in moist conditions the gills in *Stenoperla* may be functional.

The cerci in the male (Pl. 39, Fig. 29) bear on the inner sides of their short, basal joints sets of short, stout bristles, and on all the remaining segments longer more slender hairs on the outer. These latter are borne on all segments in the female.

The Male Genitalia.

The external male appendages (Pl. 39, Figs. 30 and 31) consist of a ventral, unpaired, inferior appendage, a pair of superior appendages, and an unpaired aedeagus. The sternum of the ninth segment is large, convex, and projects backwards for a short distance over the inferior appendage and forms the hypandrium or sub-genital plate, which bears on its inner surface the ejaculatory sac. The inferior appendage protects the aedeagus ventrally; whilst the superior appendages are upturned to form a short copulatory hook by means of which the male clasps the female during copulation. The aedeagus is an unpaired structure, pointed at its apex, and somewhat shorter than the appendages. It lies between the superior appendages and the anus.

The Female Genitalia.

The female (Pl. 39, Fig. 32) has no external appendages, the two oviducts uniting and opening to the exterior on a slit-like invagination on the eighth segment, which condition must represent an extremely primitive condition. There is no ovipositor.

THE INTERNAL ANATOMY OF THE IMAGO.

The Alimentary Canal.

The alimentary canal morphologically resembles that of the nymph in its division into various parts, but differs in several respects.

The Oesophagus occupies the same position as the nymphal. Posteriorly, however, at its junction with the crop, it constricts and its epithelium and intima are thrown into a large number of folds,

so that the lumen is almost obliterated. This region is surrounded by a large amount of fat.

The Crop is normal in position, but differs in that it is greatly distended with a gas the composition of which is unknown.

The Gizzard in the imago has increased in length and extends backwards as far as the fourth abdominal segment. Like the crop, it is distended with gas, this being prevented from escape into the mesenteron by the oesophageal valve.

The Mesenteron is shortened correspondingly with the elongation of the gizzard, and now lies in the fifth and sixth abdominal segments. It is much reduced in diameter and is pigmented posteriorly. The parasites referred to in the section on bionomics are extremely common.

The Hindgut is very much reduced in diameter, but displays the same structure as in the nymph. Posteriorly there is a constriction dividing it into ileum and colon-rectum, in the latter of which a trace of faece was detected.

Secretory and Excretory Glands of the Gut.

The Salivary Gland.—The salivary glands resemble those of the nymph in every respect.

The Malpighian Tubules.—These structures resemble those of the nymph except that they are of a darker yellowish brown suggesting a greater deposition of solid urates. Similarly the tubules pass forwards and are attached to the gizzard. They are all well supplied with tracheae, lie in close relation to the gonads, and arise from the mesenteron in two bands, each tubule opening into the latter by a separate opening situated on a small papilla.

The Nervous System.

The nervous system is identical with the nymphal.

The Circulatory System.

This is identical with what has already been described.

The Respiratory System.

The general nymphal respiratory plan is adhered to (Pl. 37, Fig. 24), although slight modifications have taken place to adapt it to a terrestrial mode of life. It has been shown that in the last larval instar the thoracic spiracles were present but closed; now, however, they are functional, and eight functional abdominal spiracles have been added. The main longitudinal trunk and its branches are still present, as are also the typical Y-shaped tracheae to the leg. In each of the first five abdominal segments, branches still pass downwards and outwards to the vestigial gills, a discussion of which has already been given. Each branch again sends a trachea to the gut, the muscles, and fat body, but with this difference that the large branch to the former is now connected with its fellow of the opposite side, to form a ventral commissure *not found in the nymph.* This condition occurs in the second to fifth abdominal segment, whilst the

first segment has a slightly different arrangement described below. Intersegmentally the longitudinal trunk gives off eight short, spiracular, unbranched tracheae to the first eight abdominal spiracles, except that the spiracular trachea of the first arises by the bifurcation of the tracheal trunk to the first gill, one branch of which passes to this latter, the second to the spiracle, whilst the third forms the posterior stem to the leg. This latter shortly after its origin from the spiracular trunk gives off a branch internally to join a similar branch from the opposite side, forming the first ventral commissure. This commissure is connected to the second on either side by a small longitudinal trachea running parallel and ventral to the main trunk. This again is not found in the nymph, and may or may not be a variation. In the specimen dissected the trunks to the wings were severed, since dissection was performed from the dorsal surface, but the cubito-anal branch to the forewing could be traced, and was found to be normal in position From this there seems no reason to doubt that the basal tracheae to the legs and wings are the same as for the last nymphal instar. The atria of the thoracic spiracles are now much more marked than in this latter, and it is from these that the basal tracheae to the wings arise, the trachea having migrated along the leg stems to these regions.

In the mesothorax the main longitudinal trunk gives off a fairly large branch to the muscles, represented only by a single small branch in the nymph. Together with this are the smaller branches to the muscles, the increased tracheation being correlated with the increased activity of the wing-bearing segments.

The atrium of the first spiracle is deviated forwards and constitutes that portion of the main trunk lying in the pro-thorax This by bifurcation gives rise to the dorsal and ventral head trunks, the latter of which gives off a large branch to the legs as it passes forwards. The former resembles that of the nymph, except that at the point where it curves outwards in the head, a large trachea is given off. This curves forwards and inwards to meet its fellow from the opposite side, forming a dorsal, anterior commissure between the two longitudinal trunks, a condition which is absent in the nymph.

The development of commissures is no doubt correlated with flight, this rendering it necessary to have direct communication between the trunks, thus making it possible for all parts to be oxygenated more rapidly.

The Reproductive System.

The Male Reproductive Organs.—These consist of a pair of long, convoluted tubes, the testes, extending forwards to the metathorax, where each joins its fellow from the opposite side (Pl. 40, Fig. 35) In a freshly dissected specimen each tube is seen to have an inner, opaque, central portion, and an outer transparent. Each tubule lies more or less dorso-laterally to the gut, and extends backwards, passing imperceptibly into the vas deferens. In the eighth segment

each vas deferens descends and runs backwards to the posterior region of the ninth, where it doubles back on itself, running forwards into a large vesicula seminalis (Pl. 40, Fig. 36). Each of these is joined to its fellow anteriorly, is pear-shaped, convex above and below, and opens into the ejaculatory duct by an opening of its own. There are a pair of accessory glands lying immediately beneath the vesicles, each of the former opening into the corresponding vesicle of its side. In shape they are irregular cylinders communicating with one another anteriorly. The accessory gland is revealed to be of the mesodenium type of Escherich.

The ejaculatory sac lies immediately above the hypandrium, and appears to have a portion of the median unpaired aedeagus together with the ductus ejaculatorius retracted within it.

The Female Reproductive System.—The ovaries are of the panoistic type in which no nutritive cells are present; they are two in number and extend backwards from the first abdominal segment to the eighth, lying dorso-laterally to the gut, which is much reduced in size. Each ovary has a long, straight tube, the oviduct, from which on either side are given off a large number of ovarioles (Pl. 40. Fig. 37), which increase in length from before backwards until a maximum is reached. Anteriorly on the mid-dorsal line each ovary joins its fellow. Each ovariole may be divided into three regions:—

(1) the terminal filament;

(2) the germarium;

(3) the vitellarium.

The Terminal Filament is a minute, slender prolongation of the peritoneum which invests each ovariole. All the filaments of an ovary are bound together, and anteriorly where the ovaries join they all meet and continue forwards as the median or dorsal ligament, which finds attachment on the pericardial diaphragm.

The Germarium (Pl. 40, Fig. 38) in the youngest ovarioles appears as an undifferentiated portion containing large nuclei with nucleoli. From this region the ova and follicular epithelium are developed. In older ovarioles the germarium shows the ova differentiated in linear series; this condition appears to be present in the ovarioles nearer the gonopore, the more anterior ones seemingly being of a younger nature.

The Vitellarium (Pl. 40, Fig. 37) forms the major portion of the ovariole and has the ova disposed in a linear series, each ovum being enclosed in a definite follicle and surrounded by a layer of follicular cells, which, as the ova pass down the ovariole, secrete the chorion. Meanwhile, before this occurs, the ova increase in size by the accumulation of oil droplets. Each ovum has a large nucleus.

Each oviduct extends backwards so that the ovarioles lie on top, and on the sides of the gut, and in the intersegmental region between the seventh and eighth segments, each duct descends to

the midventral line, where both join up and pass forwards for a short distance to open on the pit-like depression already described There is no uterus nor is there any vagina, the cuticle not being invaginated into the common oviducal duct, which according to some authorities is not a primitive condition

An ovoid accessory gland lies in a posterior position to the common oviduct. It opens to the exterior on the pit-like depression into which the oviduct opens. Presumably it is an albumen gland, for the eggs when freshly laid are surrounded by an oval-shaped mass of transparent substance, which disintegrates after about twenty-four hours.

THE WINGS.

The wings fold closely round the body of the insect, the right forewing completely enwrapping all but the basal portion of its fellow, and they are longer than the abdomen, projecting, when at rest, beyond its apex. Forewing longer than hind, six times as long as broad, and bright green in colour; hindwing twice as long as broad, and of a more delicate texture and colour than the forewing; anal area large, forming an unbroken contour with the rest of the wing. It folds fanwise against the body

The wings are large and cumbersome, with no coupling apparatus; flight is slow, and only short distances are covered in one flight. The wing venation is very unstable, that of two specimens differing, whilst even the wings of one side of a single individual will differ from those of the other. The greatest variation has been noticed in the branching of Rs. The cross-veins are extremely variable. Certain features, however, are constant.

VENATION.

The Forewing (Pl. 41, Fig. 39).

The forewing exhibits a primitive venation and shows less clearly the two sources of tracheation, the costo-radial and cubito-anal; Sc is concave and is distally forked into Sc_1 and Sc_2, the latter of which dips down to run along or fuse with R_1 for a short distance before curving outwards to the wing margin. C is absent, but Sc sends off a number, usually three, of cross-veins across the costal space to the anterior margin. Posteriorly the humeral veinlet comes off near the base of the wing; there is always a large space between this veinlet and the first veinlet across the costal space. About half-way along its length R, a convex vein, forks into R_1, a straight, unbranched vein running to the wing margin terminating just in front of the apex, and into the Rs, which near its distal extremity bifurcates into R_{2+3} and R_{4+5}. The former again branches into R_2 and R_3.

M, a convex vein, is fused basally with R for a short distance and is still in the primitively branched condition. Distally it bifurcates into M_{1+2} and M_{3+4}. Cu is a straight vein arising from the cubito-anal trachea, but divides distally into Cu_1 and Cu_2, the former of which is convex and has a variable number of accessory veins, usually about three. Cu_2 is a straight, unbranched, concave, weak vein lying in the anal furrow. 1A and 2A are both straight; the former is unbranched, whilst the latter divides into two. Cross-veins are present, irregularly placed on all parts of the wing, but are more strongly developed between M and Cu, and between Cu_1 and Cu_2. The humeral veinlet is constant in position; there are always sub-costal veinlets present.

The Hindwing (Pl. 41, Fig. 39).

As in the forewing, C is absent, Sc is concave and two-branched; it gives off a variable number of costal veinlets and the humeral; there is always a large space between the former and the latter. Basally R and M are fused, this vein bifurcating to give two branches R_1 and Rs + M; the former is a straight vein running directly to the margin in front of the apex. Rs + M forks giving Rs and M. This switching of Rs over to M is a constant feature and quite characteristic of the Plecoptera. Rs again divides into $R_{2 \text{ and } 3}$ and R_{4+5}, but again may be three-branched, R_{2+3} splitting into R_2 and R_3. M is two branched into M_{1+2}, M_{3+4}, and is convex. Cu is two-branched, Cu_1 having no accessory veins, whilst Cu_2 is a very weak vein lying in the anal furrow. 1A is straight and unbranched. The anal area is increased by the development of accessory veins on 2A and 3A, while there is an indication of the formation of intercalary veins Cross-veins are present throughout the wing membrane, but, as in the forewing, are irregularly placed, although more numerous than in the latter. Two strong sets strengthening the wings are developed between M and Cu, and between Cu_1 and Cu_2. The humeral veinlet is constant in position, and there are always sub-costal veinlets developed.

BRACHYPTEROUS MALES.

Four brachypterous males were taken at Ribbonwood Creek in February, 1932, associated with a normal winged female. Tillyard (1926) states that brachypterous males occur in other genera associated with females. These insects are of the same size and resemble the normal imagines in every respect, except that the wings are only one quarter of the normal size. The body is pubescent, and the gut as in normal insects is filled with a gas, both evidently being adaptations correlated with reproduction, and with the fact that these insects are never far from water, so that such adaptations would prevent drowning.

At first it was thought that they might be of a different species, but a careful examination has revealed no grounds for regarding them as such. On the contrary, it is contended that they are brachypterous males of *Stenoperla prasina,* supported by the fact that external and internal anatomy conform to the same general plan as found in the nymph and other imagines, and that the external genitalia show no difference whatsoever from the normal male. Moreover, these males were sexually mature and endeavoured to copulate with the female, which, however, very unfortunately died, together with two males, during a very severe frost. Where possible a comparison of their internal anatomy was made with that of normal imagines, and was found to be identical.

The Wings.

The wings (Pl. 42, Fig 40) are one-quarter of the normal size and lie flat on the terga of their segments, the forewings slightly overlapping the hind; the anal fan of the latter is doubled under the rest of the wing so that its dorsal surface lies ventrally on the tergum. It is slightly shorter than the fore. Both are the same colour, the wings of three specimens are olive green, whilst those of a fourth are purple in colour. When the insect is disturbed, no attempt is made to use these, but escape is effected by their very rapid running. The anterior margin of both is thickened around to the apex, and both are clothed with microtrichia. The venation is extremely variable, the wings of a single individual showing great variations.

The Forewing.—In the forewing C is absent unless the anterior thickening of the wing can be regarded as such, whilst Sc is two-branched as in the normal wing. The humeral veinlet is constant in position, and a variable number of costal veinlets pass from Sc across the costal space. Sc_2 in all cases curves downwards and is fused with R_1 for a short distance. R + M pass outwards some distance and then bifurcates into R and M. It is here that the greatest variation takes place In the more typical forms R continues towards the margin for a short distance, and then divides into R_1 and Rs; the former is a straight, unbranched vein terminating just anterior to the apex. Rs bifurcates distally into $R_{2} + {}_{3}$ and $R_{4} + {}_{5}$, but in some cases is undivided and passes out as Rs to the wing margin. M divides distally into $M_{1} + {}_{2}$ and $M_{3} + {}_{4}$, but $M_{1} + {}_{2}$ may or may not be fused at its distal extremity with $R_{4} + {}_{5}$. Cu runs some distance along the wing membrane and then splits into Cu_1 and Cu_2 (both of which are usually unbranched). A strong set of cross-veins in all cases is developed between Cu_1 and Cu_2. 1A is straight and unbranched, whilst 2A is two-branched.

The Hindwing.—The hindwing is lacking in C, and Sc is two-branched, Sc_2 fusing with R_1 as before. The humeral veinlet is constant, and there are a variable number of veinlets across the

costal space, usually three. There is a large space between the former and the latter. R + M passes out beyond the humeral, where it splits into R_1 and Rs + M. Again, R and M show the greatest variation. Rs + M bifurcates into Rs and M, the former dividing into R_{2+3} and R_{4+5}, whilst R_{4+5} in one specimen is branched into R_4 and R_5. M, however, may not branch, in which case it passes as such straight to the wing margin. Shortly after leaving R + M, Rs + M divides into Rs and M. Distally M bifurcates into M_{1+2} and M_{3+4}, the former of which may or may not be fused with R_{4+5}; the latter when present is always fused distally with Cu_1. Cu divides into Cu_1 and Cu_2, the former fusing with M_{3+4} when present. 1A is a straight, unbranched vein, whilst 2A is two-branched. 3A has a variable number of accessory veins, which increase the anal area. Nowhere on the hindwing can there be said to be a strong development of cross-veins, which occur irregularly over the whole wing membrane, and are very variable. The humeral is constant.

COMPARISON OF NORMAL AND BRACHYPTEROUS WINGS.

Forewing.

C is absent from both; Sc is two branched, and the large space between the first veinlet across the costal space and the humeral is a constant feature. In both, M arises from R, whilst this latter is typically two-branched, R_1 always being straight and undivided. Rs, however, in brachypterous forms may or may not divide; if it does, it usually bifurcates into R_{2+3} and R_{4+5}. M is two-branched, but in brachypterous forms M_{1+2} may fuse distally with R_{4+5}. Cu bifurcates into Cu_1 and Cu_2, the former, however, in the normal wing has accessory veins, which are usually lacking in the abnormal. The remaining veins are all similar, and cross-veins occur irregularly in both.

Hindwing.

The veins in these are similar except in the case of R and M. M, in the brachypterous forms, may or may not be branched into M_{1+2} and M_{3+4}, and when this latter occurs, M_{1+2} may fuse with R_{4+5}, while M_{3+4} is always fused with Cu_1. Only the former fusion has been observed as a variation in the normal wing. In the brachypterous type cross-veins are developed to a much less extent.

The venation of brachypterous male on the whole conforms with that of the normal male, but is much more variable. The distal branching of Rs, M, and Cu show the greatest variation, and the development of cross-veins is greatly reduced.

SUMMARY.

1. A review of the literature on *S. prasina* (Newm.) is given together with its classification, systematics, and distribution.

2. The bionomics of this insect is discussed. It is pointed out that for the most part the insect inhabits turbulent mountain torrents and requires water of extreme purity and high oxygen content. Its food, size, optimum, maximum, and minimum temperatures, its respiratory movements, locomotion, and reactions to light are discussed. Its enemies and known parasites are noted. An instrument for determining spot velocities in turbulent water is described.

3. The detailed anatomy of the nymphal and imaginal instars is given and differences from the generalised insect-type indicated. Chief among these are the nymphal adaptations of the tibio-tarsal region of the legs correlated with its aquatic habitat; and the presence of a gas in the crop and gizzard of the imagines. Finally, in connexion with the venation, it is concluded that M_5 is not present in Stone-flies.

4. The venation of brachypterous males is described and shown to differ but little from the general condition; it is, however, more variable. The distal branching of Rs, M, and Cu show the greatest variation, and the cross-veins are greatly reduced in number.

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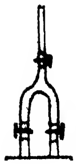


Fig. 2

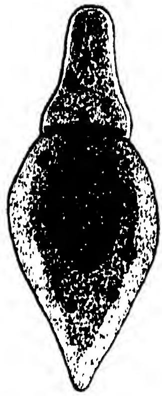
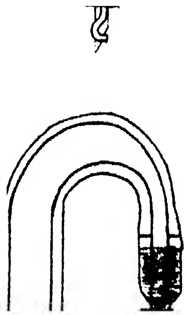
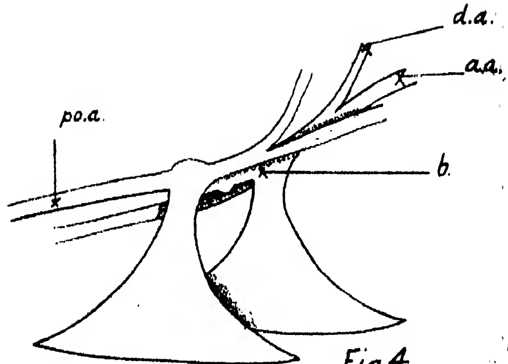


Fig. 3





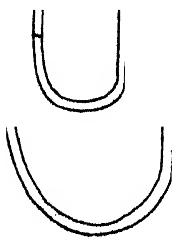


Fig. 1

Fig 4

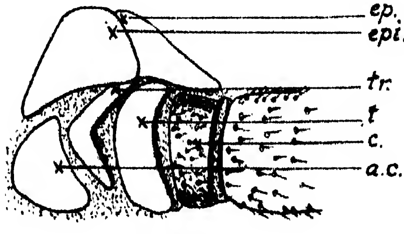


Fig. 5

FIG. 1.—Sketch of Pitot tube. FIG. 2.—Side view basal portion of Pitot tube.
FIG. 3.—Gregarine from mesenteron last nymphal instar. × 75.
FIG. 4.—Tentorium side view. FIG. 5.—Pleurites of nymph.

po.a.—posterior arm of tentorium
d.a.—dorsal arm of tentorium
a.a.—anterior arm of tentorium
b.—body of tentorium
ep.—epimeron
epi.—episternum
tr.—trochantin
t.—trochanter
c.—coxa
a.c.—antecoxal plate

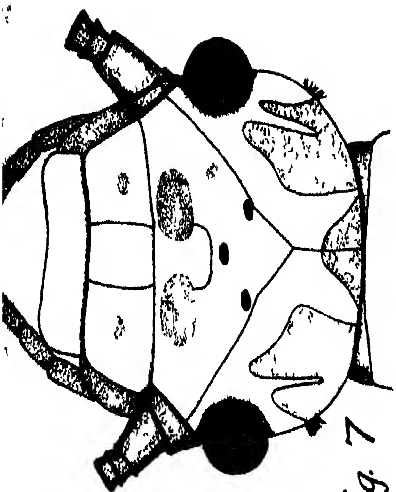


Fig. 7

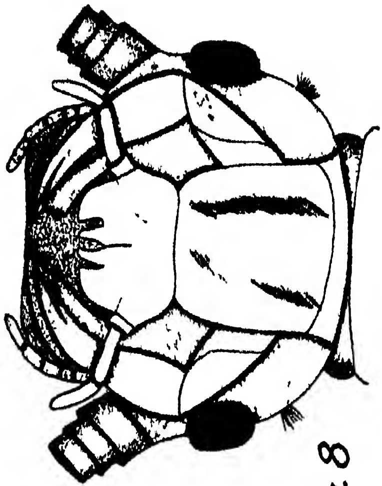


Fig. 8

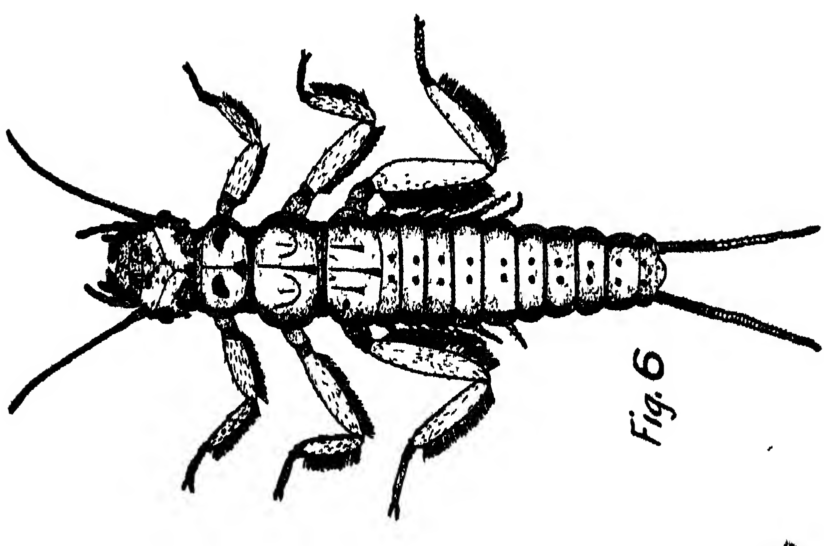


Fig. 6

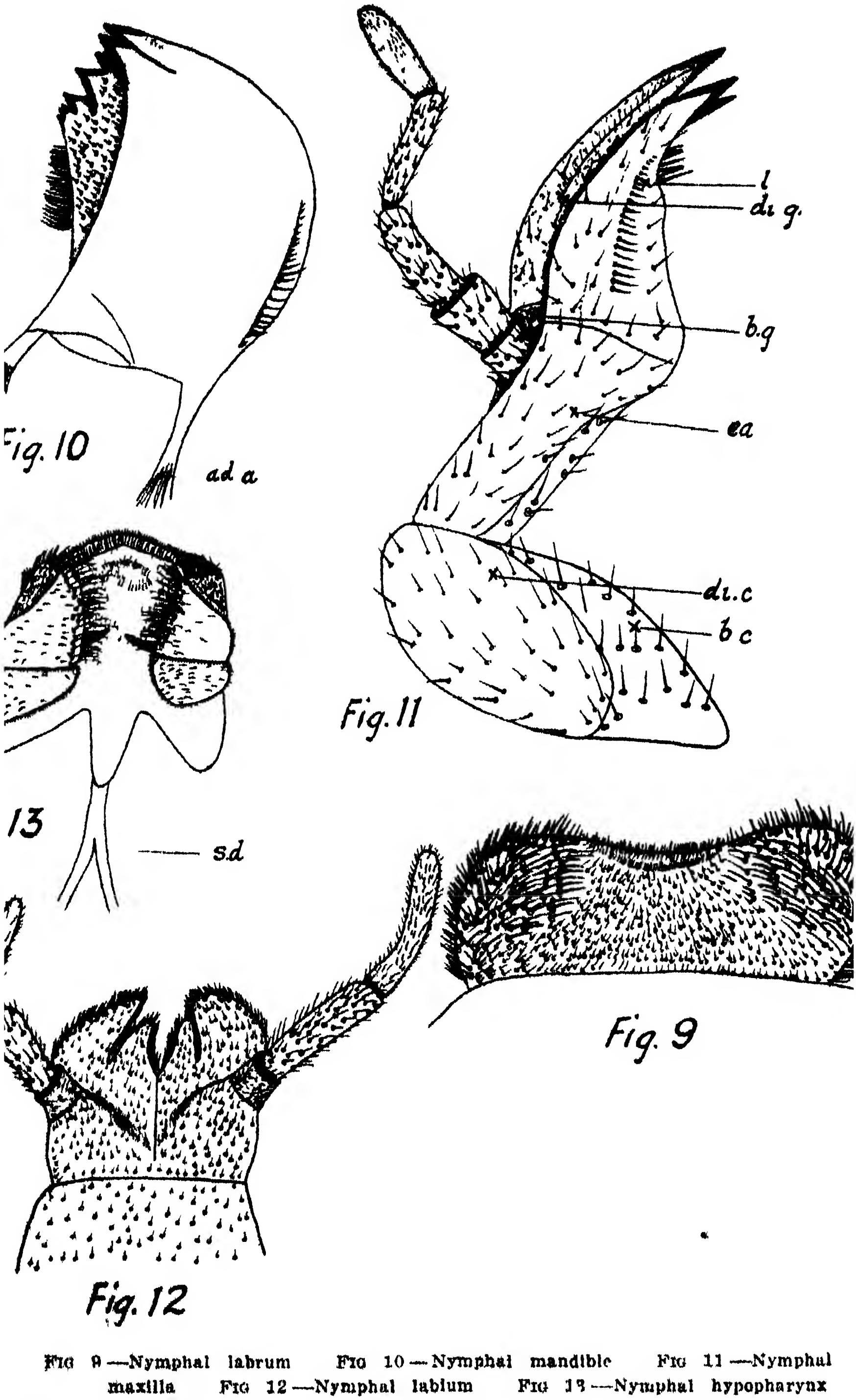
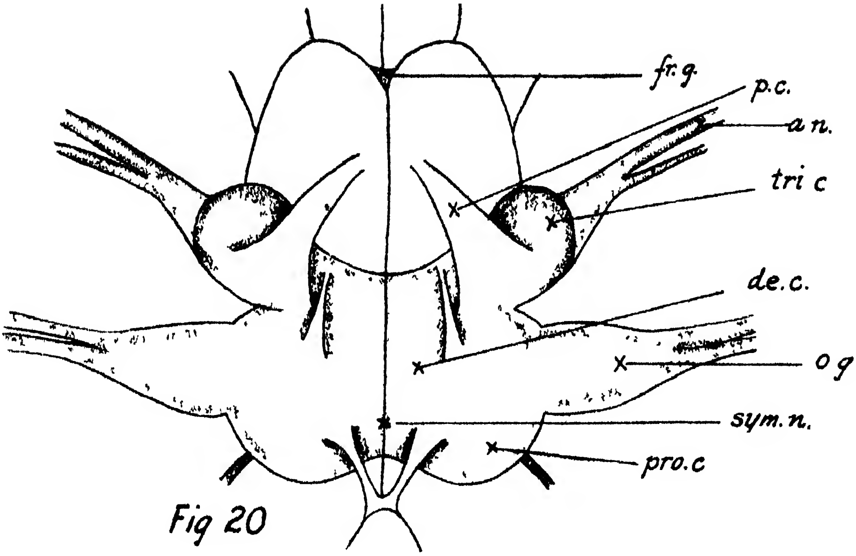


FIG 9—Nymphal labrum FIG 10—Nymphal mandible FIG 11—Nymphal maxilla FIG 12—Nymphal labium FIG 13—Nymphal hypopharynx

ad a—adductor apodeme
s d—salivary duct
l—lacinia
di g—distigalea

b g—basigalea
ea—eustipes
di c—disticardo
b c—basi-cardo



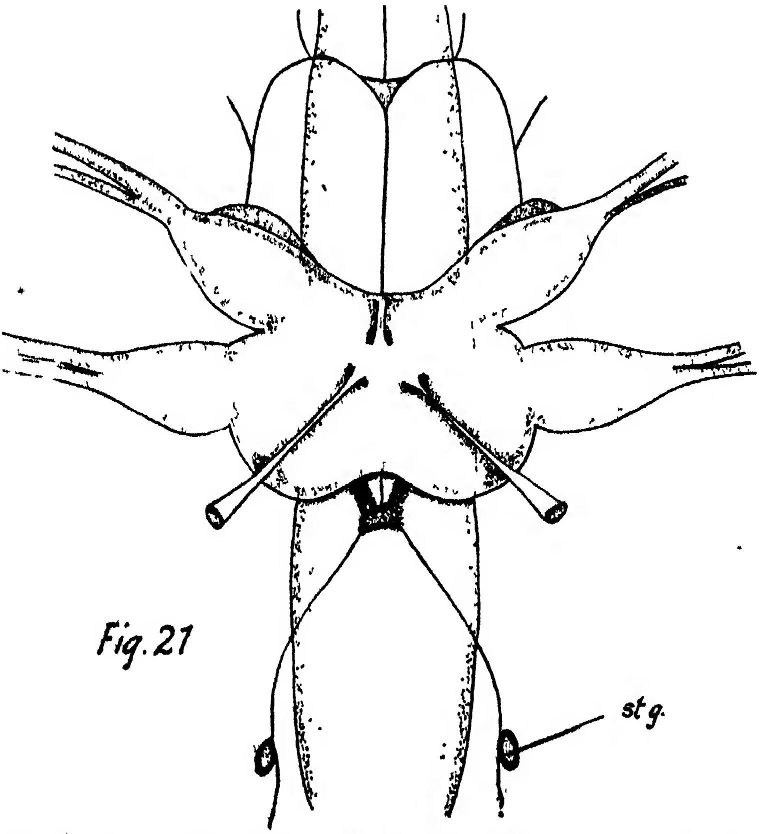


FIG 20—Brain and sympathetic nerves ventral aspect FIG 21 -Dorsal aspect ditto

fr g —frontal ganglion
p.c —paroesophageal connective
a n —antennary nerve
tri c —triterocerebrum
de c —deuterocerebrum
o g —optic ganglion
sym n —sympathetic nerve
pro c —proterocerebrum
st g —stomachic ganglion

FIG 22—Ventral nervous system of nymph (right side) FIG 24—Ditto imago FIG 23—Respiratory system of nymph

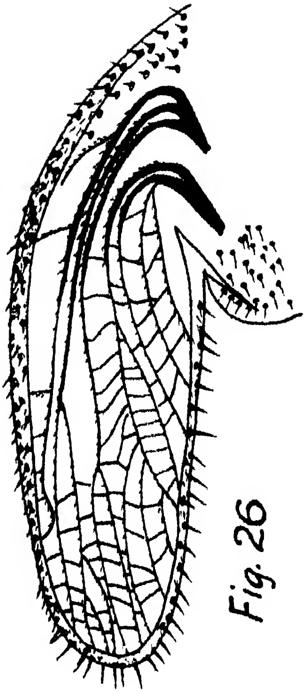


Fig. 26

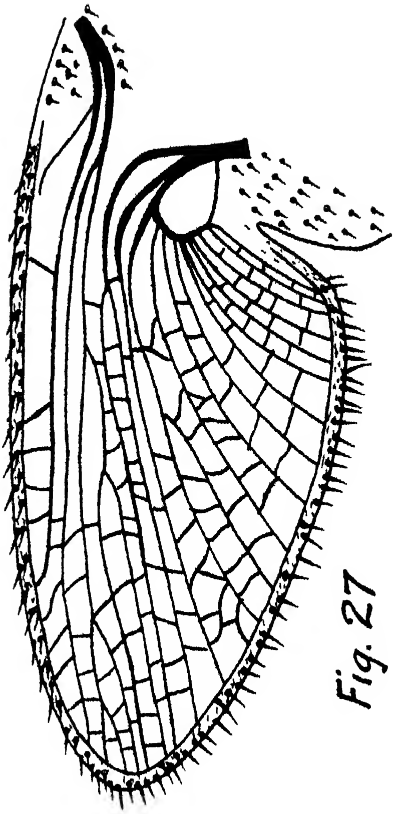


Fig. 27

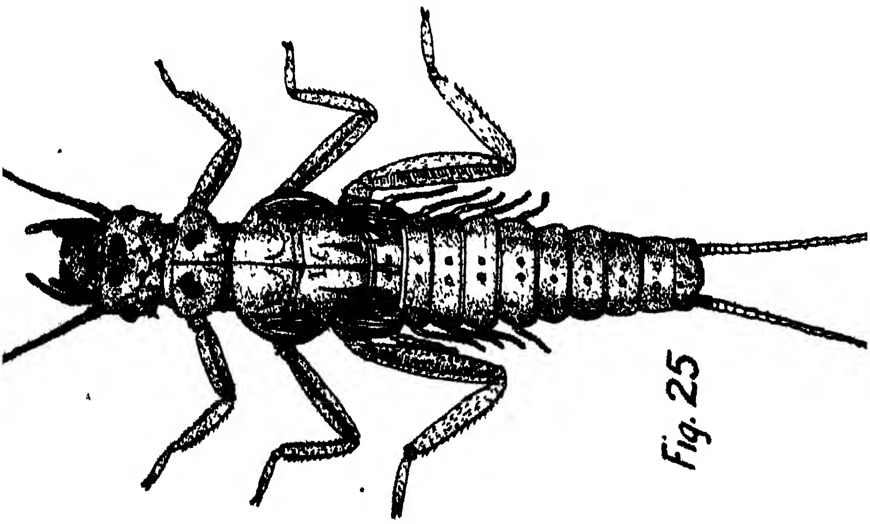


Fig. 25

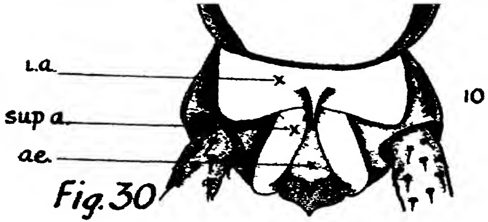


Fig. 30

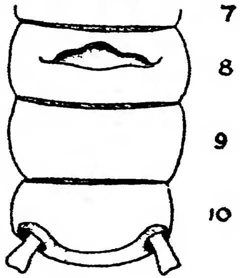


Fig. 32

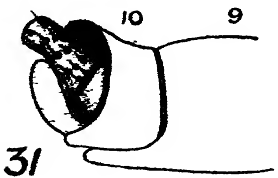


Fig. 31

Fig. 29

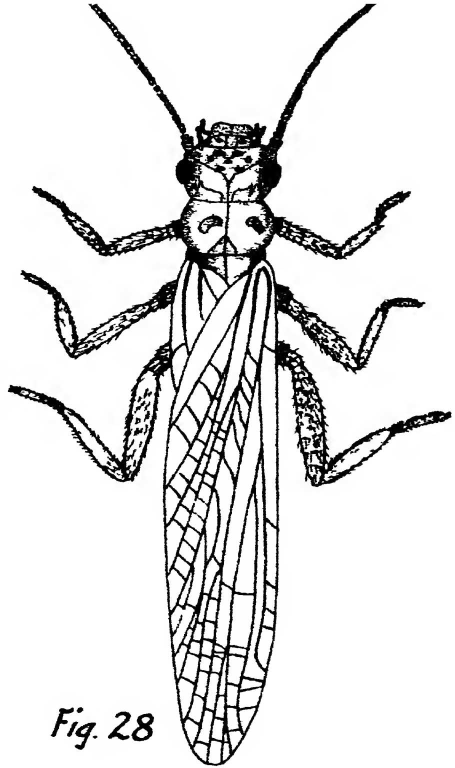


Fig. 28

FIG 28—*S prasina* imago × 4 FIG 29—Male cersus showing bristles FIG 30—Male genitalia ventral aspect FIG 31—Ditto side view FIG 32—Female genitalia ventral aspect

hy—hypandrium i a—inferior appendage sup a—superior appendage ae—aedeagus

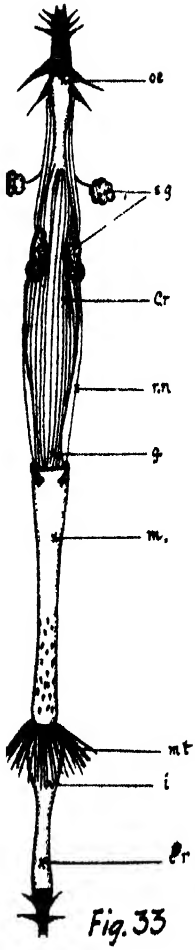


Fig. 33

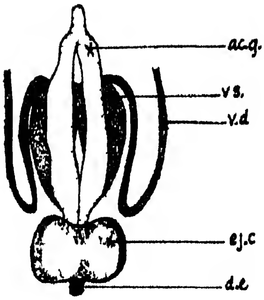


Fig 36

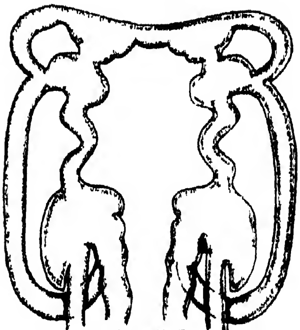


Fig 35

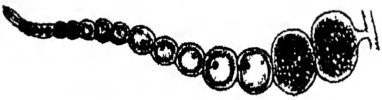


Fig 37

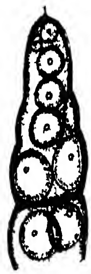


Fig. 38

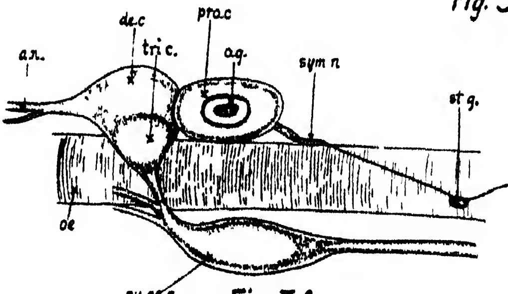


Fig. 34

33.—Alimentary canal of nymph. FIG. 34.—Brain and suboesophageal ganglion *in situ*, side view. 35.—Anterior region testes. FIG. 36.—Male accessory organs, ventral aspect. FIG. 37.—An ovariole. FIG. 38.—The germarium.

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oe.—oesophagus
s.g.—salivary gland
cr.—crop
r.n.—recurrent nerve
g.—gizzard
m.—mesenteron
m.t.—malpighian tubules
i.—ileum
c.r.—colon-rectum
ac.g.—accessory gland
v.s.—vesicle seminalis
v.d.—vas deferens

ej.c.—ejaculatory sac
d.e.—ductus ejaculatoris
a.n.—antennary nerve
de.c.—deuterocerebrum
tri.c.—triterocerebrum
pro.c.—proterocerebrum
o.g.—optic ganglion
symn.n.—sympathetic nerve
st.g.—stomachic ganglion
oe.—oesophagus
su.oe.g.—sub-oesophageal ganglion

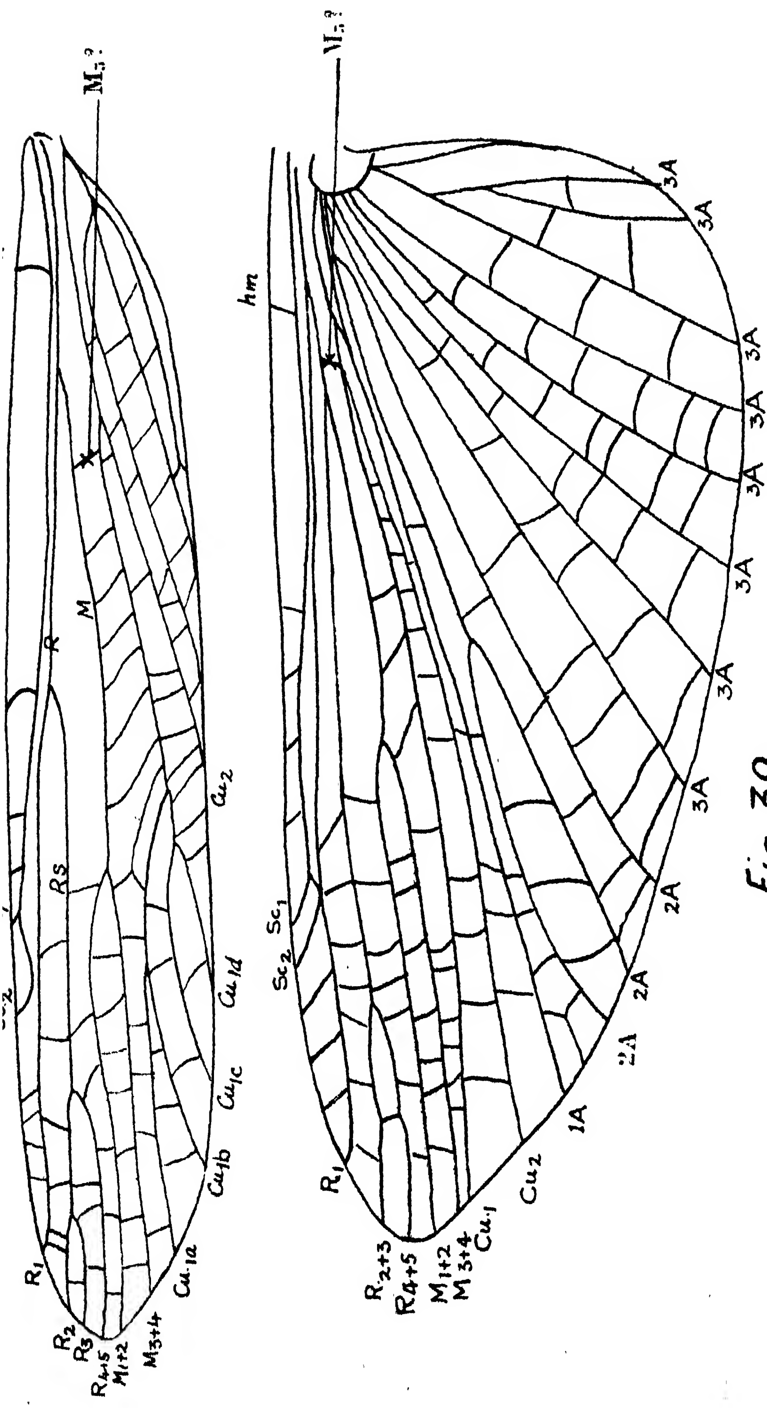


Fig. 39

FIG. 39.—Normal venation, S. pruinus.

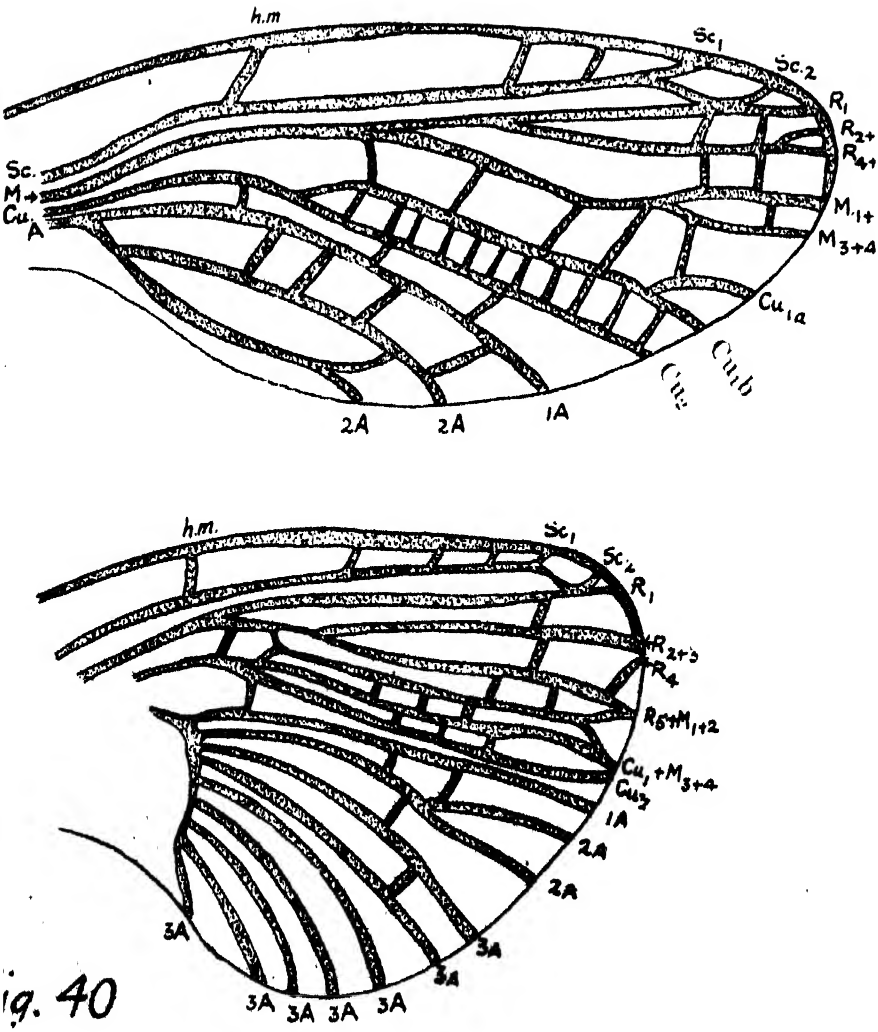


FIG. 40.—Brachypterous venation, *S. prasina*.

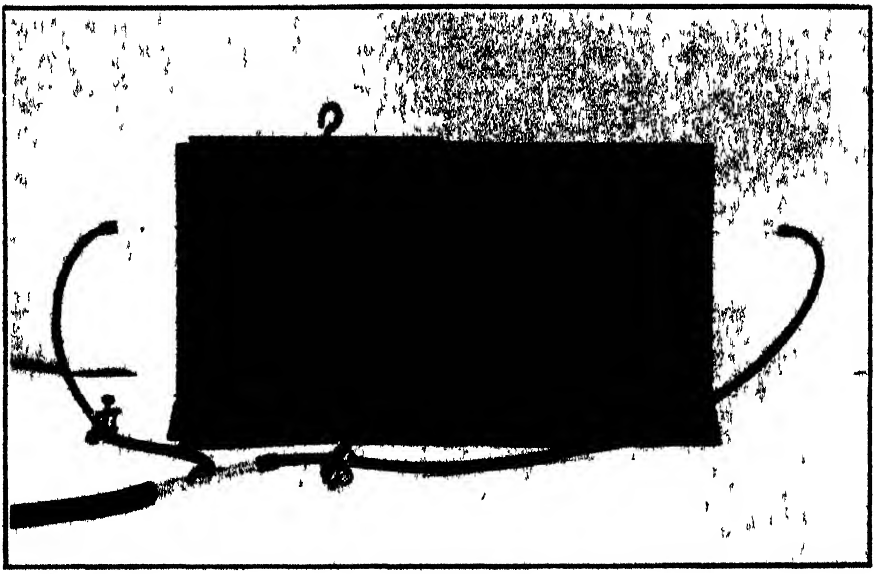
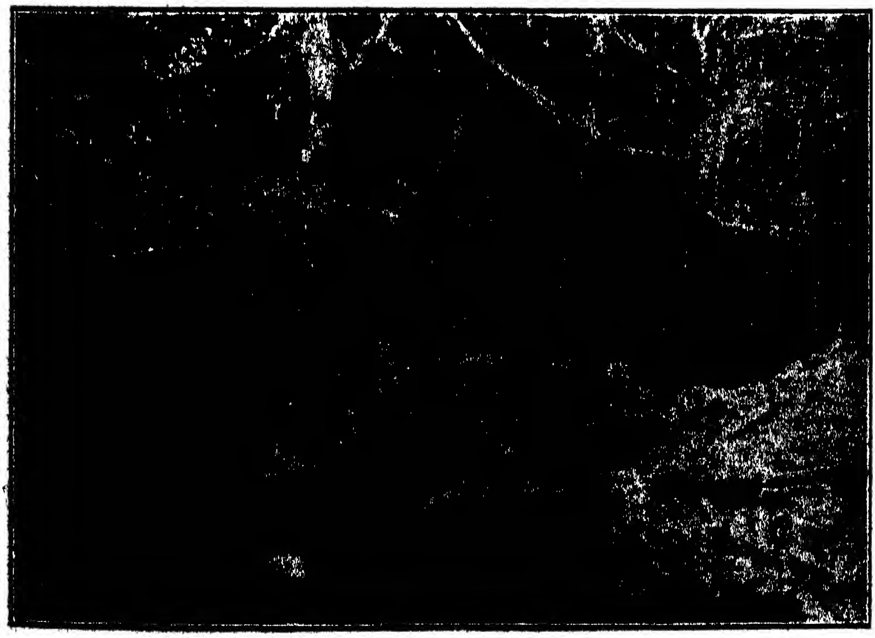


FIG 41.—Apparatus used to determine reactions to light

FIG 42.—Ribbonwood Creek, Cass

Fig. 43.—Putau Stream looking towards its source.

Fig. 44.—Mount Misery, Cass, with Misery Creek in valley to the right.



TRANSACTIONS

AND

PROCEEDINGS

OF THE

ROYAL SOCIETY OF NEW ZEALAND

VOL. 64
(Quarterly Issue)

PART 3, MARCH, 1935.

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By the Royal Society of New Zealand Act, 1933,* the New Zealand Institute constituted by the New Zealand Institute Act, 1908, was abolished, and, with His Majesty's gracious approval, a body was constituted as successor to the New Zealand Institute to be called the Royal Society of New Zealand. The new Act is dated 6th December, 1933; from that date the name of the New Zealand Institute disappeared and the new title was adopted.

The Royal Society of New Zealand is now in possession of all the properties and has assumed all the responsibilities of the New Zealand Institute. All members and officers of the New Zealand Institute at 6th December, 1933, continue as members and officers of the Royal Society of New Zealand. Regulations, rules, resolutions, and orders became as effective under the Royal Society of New Zealand as they were under the New Zealand Institute, and all matters and prooceedings begun under the New Zealand Institute may be continued, completed, and enforced by the Royal Society of New Zealand.

The Royal Society of New Zealand Act is a machinery measure for effecting a change of title. Under the New Zealand Institute Act, 1908, the Board of Governors was the corporate body; the Royal Society Act makes the Society the corporate body. The Act effects improvements in the method of conducting the affairs of the Society. The Governor-General becomes Patron instead of being a full member of the Board now called a Council. In the long title of the Act the words "a body for the promotion of science" revives an expression of purpose which was present in the Act of 1867 originally constituting the New Zealand Institute Act, but was omitted from later Acts dealing with the New Zealand Institute.

In other minor matters the Act gives that authority for doing what the New Zealand Institute has been in the habit of doing without authority. The Act specifies in detail the Society's power of making rules. Clause 11 repeats Section 7 of the Finance Act, 1925, stating the amount of the annual endowment from Parliament to be £500.

* Which will be printed later in the Volume.

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Part III, 1935.

GEOLOGY.

ZOOLOGY.

MISCELLANEOUS.

LIST OF PLATES.

Note on the Occurrence in New Zealand of the Myriapod Polyxenus.

By C. M. HECTOR.

[*Read before the Wellington Philosophical Society, November, 1933, received by the Editor 10th December, 1933; issued separately March, 1935.*]

THIS organism, although perhaps observed, appears not to have been recorded hitherto in New Zealand. It was brought to my notice in May, 1932, by Mr C. G. G. Berry, who found it in a rock cutting at Northlands, Wellington. I have since found it in similar situations at Lowry Bay and Belmont, i.e., in cracks on rock faces: always on an aspect away from the sun. I understand that it has also been seen under the bark of trees in several parts of New Zealand. It is an organism of very wide distribution both in space and time. It is widely distributed in Europe, and allied forms have been found in the West Indies, North and South America, Ceylon, and elsewhere. Fossil forms are found as far back at the Carboniferous (Pocock, 1901). In the Cambridge Natural History (Sinclair, 1901) a fossil form is illustrated which is not very different from the present-day forms. Here, again, as with the Tuatara and other organisms, New Zealand possesses a link with the remote past. As found in rock cuttings the organism occurs in little clusters of 10 to 15 individuals. The clusters comprise individuals in several stages of development, i.e., adults and immature forms together with nests containing eggs or empty egg cases. (Figs. 1 and 2.) The mature individuals are minute, being 2 to 3 mm. long. They are difficult to see, on account of their colouring so closely resembling the rock surface on which they lie. They are best recognised by their pearly-white, brush-like tails. (Fig. 3.) When undisturbed, they are quiescent for considerable periods; but if disturbed, move about very actively. They are fascinating objects to watch under a low power binocular microscope. The body consists of a number of segments which varies with the age of the individual, as also does the number of legs. Thus in a newly-hatched individual the number of segments is five and the number of legs three pairs. One individual 2·75 mm. long exhibited 10 segments and 20 pairs of legs, while another individual 1 75 mm. long exhibited 7 segments and 10 pairs of legs. (Fig. 4.) Each segment of the body is provided dorsally with a double row of bristles, and there are tufts of bristles on lateral projections on each segment. These bristles are plume-like. They are shown in the accompanying photomicrographs. (Figs. 5 and 6.) The tail is composed of two kinds of bristles, viz.:—

(a) Plume-like (Fig. 5).

(b) Crook-like (Fig. 7).

They are arranged in two lateral bunches or pencils (whence the specific name Lagurus given to the European species). Between the lateral pencils is a medial bunch comprising a small number of bristles which, however, lack the pearly lustre of those in the lateral pencils.

The crook-like bristles are very characteristic. They have long been known and used as a test object for microscope objectives. An excellent photomicrograph of one of these bristles appears in the frontispiece to Carpenter and Dallinger's work on the Microscope (Carpenter and Dallinger, 1901). It was the characteristic appearance of this well-known bristle which led to the local recognition of the organism. The nests, of which 4 to 6 may occur in a cluster, tend to adhere to one another. On closer examination they are found to consist entirely of the crook-like bristles from the tail of the Myriapod. Fig. 9 shows the edge of a nest with the crook-like bristles. Clustered in these nests are a number of oval eggs with apparently chitinous cases. The number of eggs in a nest is from four to eight or more. The size of the eggs is about 0 4 by 0 3 mm. (Fig. 8). No doubt the nest-like wrapping of bristles round the eggs is for protection of the eggs both against mechanical injury and against marauders. Why are only the crook-like bristles used for this purpose? Probably because they will cohere better. The question now arises as to the procedure in obtaining the bristles. Are they purposely shed or discarded bristles, or are they pulled out of the brush of a living Myriapod? They are probably derived from the living organisms, for it is to be noted that many of the individuals captured at this time of the year (spring) show varying degrees up to complete denudation of their tails. Mr Gilbert Archey has kindly undertaken to identify the species for me, but has not yet had time to complete his report. In passing, it may be noted that the form found in New Zealand resembles very closely *Polyxenus lagurus*, as figured and described in the literature available. The crook-like bristles, however, appear to have more barbs than are shown in the illustration in Carpenter and Dallinger's book, above referred to. One authority in Germany (Sorauer, 1925, p. 83) ascribes to *Polyxenus* the conveying of the spores of potato disease.

References.

Carpenter, W. B., and Dallinger, W. H., 1901. *The Microscope and Its Revelations*, 8th ed.

Pocock, R. I., 1901. In *Encyclopedia Brittanica*, 11th ed., vol. 18, p. 470

Sinclair, F. G., 1901. Myriapoda. *Cambridge Natural History*

Sorauer, P., 1925. *Handbuch von Pflanzen Krankheiten*, vierter Auflage, Bd. IV, Berlin, Paul Pariy.

1 General view of rock surface showing *Polyxenus* and nests × 3

2 A "nest" showing eggs and bristles. × 13

3 Adult *Polyxenus* showing bristles on body and pencil tail × 16.

4 Immature *Polyxenus* showing bristles on back and lateral tufts. × 35.

Photos by C M Hector.

Spirotrichosoma magna (n. sp.) from a New Zealand Termite.

By G. A. H. HELSON, M.Sc.,

Biological Research Laboratory, Canterbury University College, Christchurch, New Zealand.

[*Read before Canterbury Philosophical Institute, 6th December, 1933; received by the Editor 4th January, 1934; issued separately March, 1935.*]

ALTHOUGH a large amount of literature on the Protozoan fauna of termites exists, yet up to the present time there has been no record of the fauna belonging to the New Zealand species. While examining *Stolotermes ruficeps* (Braur), the writer found that the ileum, like that of other termites, possessed a very large protozoan fauna composed of the large flagellate *Spirotrichosoma magna* n.sp., which is described in the present paper. Other protozoa were present also, but to a lesser extent. The genus is new, and was created by Sutherland in 1933, but the original description is very inadequate. This author distinguishes the genus, *Spirotrichosoma*, by the structure of the axial organ or "centroblepharoplast" and its relation to the flagellar bands, but does not enter into a minute description of these structures, nor does this author give their detail when describing the species of this genus. However, the flagellar bands in the flagellate about to be described are two in number, are coiled in a spiral of about one and one-half to two complete turns, and are intimately connected with the "centroblepharoplast" of Sutherland. These two conditions, together with the fact that this flagellate is present in another species of termite belonging to the same genus from which *Spirotrichosoma* was obtained, leave no doubt that the two flagellates are of one and the same genus, but different species.

The following is a description of *Spirotrichosoma magna* n.sp., but some minute detail is omitted because the lenses available did not give good definition at high magnifications.

TECHNIQUE.

Living protozoa were examined in a drop of water, saline solution of 0·75 per cent. concentration, or in modified Ringer's solution under paraffin sealed cover-glasses on ordinary slides. Since the protozoa were of a dark-brown colour due to the presence of wood fragments, termites were fed on filter-paper for a week or ten days in order to render the cytoplasm clear and so enable the internal structures to be seen.

Various intra-vitam stains were used such as Neutral Red, Methyl Green, Methylene Blue, and Janus Green. These were dissolved in absolute alcohol, a drop of which was placed on the slide and allowed to evaporate before the protozoa were transferred to the slide. A solution of iodine in potassium iodide was used to demonstrate the flagella; this solution also rendered visible the surface ridges of the

posterior region of the body. Permanent mounts were made as wet cover-slip smears fixed in the following:—Hot Schaudin's, Bouin's, Carnoy, Petrunkewitsch, and La Cour's solutions (1929), all of which gave excellent results.

Smears were stained with Delafield's, Heidenhein's, and Shortt's Haematoxylin, Acetic-alum-carmine, Borax-carmine, and Picro-carmine; the first three were countered-stained with acid Fuchsin, Eosin, or Erythrosin.

Occurrence and Activities.

The protozoan is found densely packed in the ileum of *Stolotermes ruficeps,* and together with fragments of wood and other smaller protozoa almost completely fills the lumen of the intestine. Kofoid and Swezy (1919) noted that the smaller flagellates occupy the region near the walls, but this has not been verified for this species of termite.

The intestinal fluid is thick and milky, and through this liquid the flagellates move slowly by means of their flagella, using their mobile rostra to push a pathway through the medium. The chief locomotor flagella appear to be the long anterior ones which are directed forwards and sideways. The flagella or cilia covering the posterior region of the body are uniformly distributed and are directed backwards. They have a characteristic wave motion both when the organism is in motion and when it is at rest, the waves passing from the base of each flagellum to the tip. The wave movement of the anterior flagella begins at the top of the rostrum and passes down and around the anterior, flagellar bands, a new wave movement commencing at the top again.

Morphology.

Size and Shape.

Average length ·3 mm.; average breadth ·2 mm. The organism (Fig. 1) is broadly oval with the posterior end bluntly pointed, tapering to the apex, whilst a definite anterior constriction distinguishes a head region from the rest of the body.

The body is divided into three regions:—

(1) An anterior, clear, dome-shaped cap or operculum, which is covered by a very delicate membrane. Its base is slightly concave, whilst its cavity is filled with a perfectly transparent, homogeneous substance. In the base of the cap there is a refractile, hemispherical granule, the blepharoplast, which is visible in the living organism.

(2) The rostrum proper, which together with the cap comprises the head region. From this region the long anterior flagella arise from the two flagellar bands.

(3) A large posterior region increasing in width from before backwards to about half its length, where the broadest part is situated. Posteriorly it tapers to the bluntly-pointed apex. This region is clothed with long, backwardly directed, uniformly distributed flagella. It is composed chiefly of endoplasm, in which are fragments of wood detritus. The endoplasm is invested with a thin sheath of ectoplasm.

Surface-ridges.

The posterior region of the body possesses a large number of low, rounded, transverse surface-ridges with grooves in between.

The Flagella.

The flagella may be divided into three sets:—

(1) Those arising from the rostral tube,

(2) Those arising from the anterior flagellar bands, and

(3) Those clothing the posterior region of the body.

The first two groups form the anterior tuft, are directed forwards and sideways, and their movement is independent of those belonging to the last group.

(1) The flagella belonging to this group penetrate through the ectoplasm, their roots finding attachment to the rostral tube which is formed from the fused basal granules of these flagella.

(2) The flagella of group two penetrate through the ectoplasm and endoplasm of the rostrum to the two spirally twisted, flagellar bands, which have one and one-half to two complete turns that increase in width from before backwards. The roots of the flagella and the nature of these bands are clearly seen when these structures are viewed from above (Fig. 2). As has already been stated, movement of these two groups of flagella commences at the top and progresses down and around the anterior axial organ.

(3) The flagella covering the posterior region of the body emerge from the grooves between the surface-ridges as was found by Kirby (1932). Their basal granules and plates have not been observed.

THE ECTOPLASM.

The ectoplasm is thickest in the rostrum and decreases in thickness posteriorly towards the body, which it invests as a thin layer The differentiation of the anterior ectoplasm into three layers as found by Kirby (1932) could not be determined owing to poor definition under high magnification, but it appears probable that this region is divided into:—

(1) An outer layer which is traversed by the basal portions of the flagella,

(2) The middle layer likewise traversed by the flagellar roots and probably of a fluid nature, and

(3) The innermost layer which includes the basal granules of the flagella. These latter are intimately fused to form the rostral tube.

BLEPHAROPLAST.

The hemispherical granule in the base of the cap is latterly considered by Franča (1916-18) to be a blepharoplast. Kirby (1932) accepts this term, and, as his reasons for doing so are reasonable, it is accepted in the present paper. As Kirby points out, most workers have either overlooked this structure, or have described it inaccurately. Sutherland (1933) appears to have overlooked it, too, as it is not

figured at all. Presumably this author did not see the deeply staining ring of Kofoid and Swezy (1919), nor does she appear to have seen Kirby's paper, as she adopts the nomenclature of the former, which Kirby has shown needed revising.

In *Spirotrichosoma magna* the blepharoplast is connected to the rostral tube from which the flagella take their origin. This, together with the fact that a rhizoplast has been traced from the nucleus to the base of the rostral tube, also suggests that the granule is of a blepharoplastic nature. It is probable that the rhizoplast passes up the rostral endoplasm to the blepharoplast.

The Rostral Tube.

The rostral tube was termed the "centroblepharoplast" by Kofoid and Swezy (1919). Kirby's term rostral tube is adopted in the present paper, however. It consists of a tube which increases in diameter from before backwards; anteriorly it is joined to the blepharoplast whilst posteriorly it gives off the two deeply stainable, flagellar bands. Its walls are solid and deeply stainable, and since the anterior flagella arise from these it is probable that the walls are composed of the fused basal granules; hence it is not to be differentiated from the rest of the layer of basal granules. With Heidenhein's Haematoxylin (Figs. 2 and 3) it stains an intense black, appearing as a solid rod, with the blepharoplast also deeply stained as a small knob situated at the anterior end. With acetic-alum-carmine it appears as two rods, but in these specimens it is not possible to trace the rhizoplast up the rostral tube to the blepharoplast. In the former, on the other hand, this filament is clearly visible passing from the nucleus to the base of the rostral tube (Fig. 3).

The Flagellar Bands.

There are two bands of deeply stainable material given off from the posterior end of the rostral tube in the form of a double spiral, which has about two complete turns as mentioned before. These turns increase in diameter from before backwards and enclose the nucleus. The bands, when viewed from above (Fig. 2), show minute, deeply staining plates situated on their external borders. These are undoubtedly the basal plates of the flagella, and since the bands are intimately connected to the rostral tube and give rise to the flagella, like this latter, they must be comprised of the fused basal granules of the flagella. That this is the case is also indicated from the fact that the movement of the flagella arising from these bands is co-ordinated with that of the flagella arising from the rostral tube itself.

The Parabasal Apparatus.

A number of filaments (Fig. 1), which stain intensely with Heidenhein and which are scattered throughout the anterior endoplasmic region, are considered to be parabasal apparatus. Sutherland (1933) makes no mention of having observed these structures in the other two species, but it is probable that they possess an apparatus similar to the one herein described. The whole apparatus lies posterior

to the nucleus and is not connected with it. Kirby (1932) states that in what are probably the more primitive species the cords do not come into contact with the nucleus. Again, in some species of *Pseudotrichonympha,* the apparatus, while it lies anterior to the nucleus, does not come into contact with it, so that the dispersed apparatus in the species here described is not an unusual feature.

THE NUCLEUS.

Average length 24 μ; average breadth 15 μ. It is pyriform, with its more pointed end directed forwards, and varies slightly in size according to the individual. It is almost always situated in the anterior end, and is enclosed by the flagellar bands as already described. In two abnormal cases the nucleus has been observed to lie nearer the posterior end. Internally the chromatin is dispersed as irregular separate granules in the nucleoplasm, which is finely granular. From the anterior end, the rhizoplast is given off.

Diagnostic Characters.

Average length of body ·3 mm.; average breadth ·2 mm. It differs from *S. obtusa* and *S. capitata* in its large size and greater breadth in proportion to its size. Body broadly oval, bluntly pointed, and tapering to apex posteriorly; anterior end constricted to form a rostrum from which arise the anterior flagella; entire body posterior to rostrum clothed with long flagella emerging from grooves between surface ridges. Nucleus average length 24 μ; average breadth 15 μ, pyriform, with more pointed end directed forwards. There is an anterior hemispherical granule attached to a more posterior rostral tube, which gives off two flagellar bands posteriorly, the latter of which form a double spiral of one and one-half to two complete turns increasing in diameter from before backwards and encircling the nucleus. The parabasal apparatus is diffuse and lies posterior to nucleus.

SUMMARY.

A new species of Hypermastigote, *Spirotrichosoma magna,* is recorded from the New Zealand termite *Stolotermes ruficeps,* and its occurrence, activities, and morphology are described.

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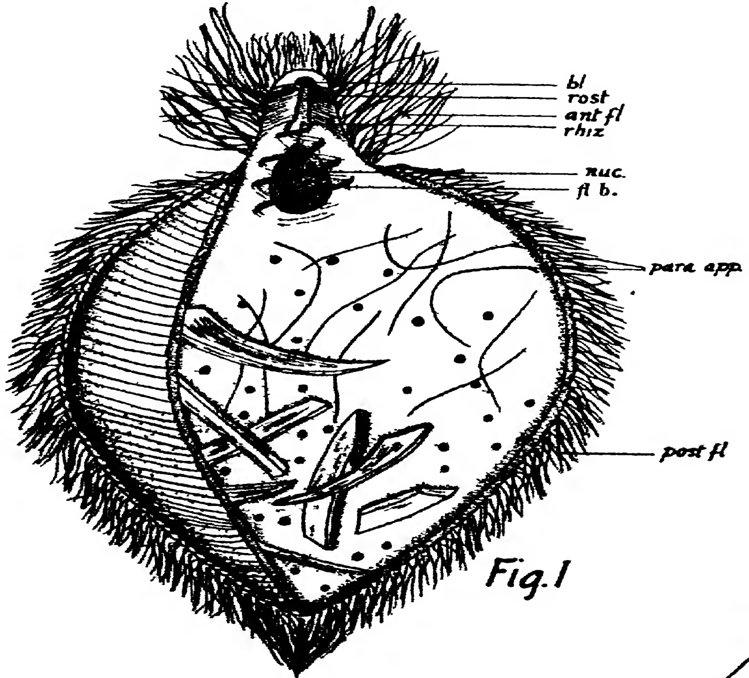

Fig.1

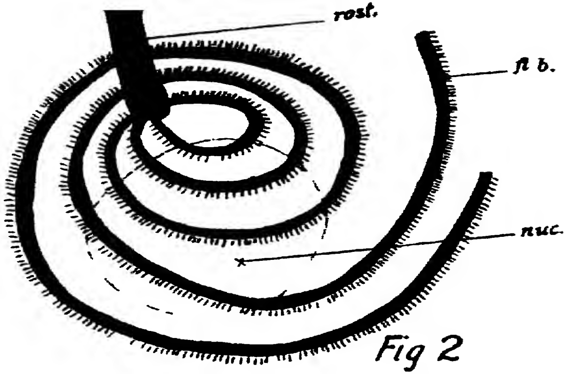

Fig 2

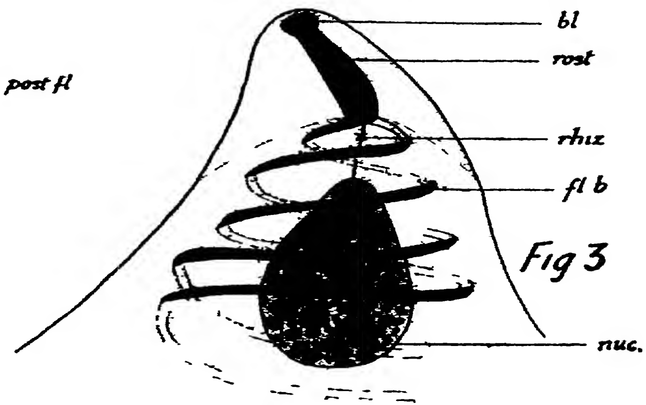

Fig 3

ant fl, anterior flagella, bl, blepharoplast fl b, flagellar band nuc, nucleus, para app, parabasal apparatus, post fl, posterior flagella, rhiz, rhizoplast rost, rostrum

FIG 1—*Spirotrichosoma magna* n sp × 450 Composite drawing FIG 2—Blepharoplast, rostral tube and flagellar bands of *S magna* stained with Heidenhein and showing basal plates of the flagella Oc 5, obj 1 12 FIG 3—Head of *S magna* showing blepharoplast rostral tube, flagellar bands nucleus and rhizoplast Oc , obj 1 12

Hydrographical Observations in Auckland Harbour.

By W. K. HOUNSELL.

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IN connection with an Ecological Survey of the Auckland Harbour, being carried out by the staff of the Auckland Museum, it has been found that many observations have been taken from time to time for such purposes as harbour improvement and city drainage schemes While many of the details refer to local problems, there still is a large amount of valuable data filed by local authorities for their own particular purposes. An endeavour has, therefore, been made to select such data as may be of some use to the Survey Staff, and to co-relate various series of observations from the sources available.

Acknowledgments must be made to Mr D. Holderness, Engineer, Auckland Harbour Board, and to Mr H. H. Watkins, Engineer, Auckland Drainage Board, for the use of information regarding various aspects of the Harbour; to Commander E. Lyon Berthon, D.S.C., Naval Department, Devonport, for the use of a series of sea temperatures, etc.; and to the Government Meteorologist and the Inspector of Fisheries for much information of a varied nature. The author also wishes to thank Mr Dilwyn John and Mr G. R. Deacon, Director of Research and Hydrologist respectively, of the R.R.S "Discovery II," for their practical help and advice and for the use of valuable literature in the ship's library.

TOPOGRAPHY.

The Auckland Harbour is a tidal estuary, situated at the south-western end of Hauraki Gulf, and running in an east and west direction. Its geographical position is lat. 36 deg. 49 min. 56 sec. S., long. 174 deg. 47 min. 57 sec. E., the observation spot being near the Devonport Wharf on the north side of the harbour. It is officially described as all that area of tidal water within a line drawn from the eastern head of Tamaki River to Park Point, Waiheke Island; thence by high water mark to the western entrance to Owhanaki Bay; thence by a straight line to Home Bay Point, Motutapu Island, and thence by high water mark along the southern and western shores of Motutapu Island, and the southern and western shores of Rangitoto Island to a position where a straight line projected at 270 deg. passes through the Rangitoto Beacon to the mainland. For the purposes of the ecological survey, however, these limits have been exceeded, and work has been carried out to the north-east, the south-east, and along the northern shores of Rangitoto Island. The harbour has a total area of 77 square miles and a water frontage of 198 miles. It has a total length of 54 miles and an average width of 1 mile.

No large amount of fresh water discharges into it, and it may therefore be regarded as a purely tidal estuary.

The depth of water in the main channels varies from 5 to 12 fathoms, while the bottom is largely mud with smaller areas of rock, sand, and shell, or mixtures of these.

The harbour may be divided into three parts, the Outer, Inner, and Upper Harbours.

The Outer Harbour consists of all the area to the north and east of a line drawn from North Head to Bean Rock Light, thence along the crest of the reef to Bastion Point. It includes the Rangitoto Channel, which runs in a northerly direction with an average depth of 6 fathoms; the Motukorea Channel, which runs in an easterly direction with an average depth of 4 fathoms; and the Motuihi Channel to the eastward of this with an average depth of 9 fathoms. Between Motuihi Island and Waiheke Island lies another channel which receives the tidal stream from an area outside the harbour limits, and which joins the Motuihi Channel to the north-east of Motuihi Island, and passes out between Motutapu and Waiheke to the open waters of Hauraki Gulf Opening into the Outer Harbour on the southern side is the Tamaki River, which runs north and south, and is a long, narrow, tidal river with mud flats exposed at low water.

The Inner Harbour, which includes the commercial port of Auckland, lies to the westward of the Outer Harbour to a line drawn from Kauri Point to Point Chevalier Reef Two large bays, largely exposed at low water, open into it, Shoal Bay on the north, and Hobson Bay on the south The Inner Harbour has an average depth of 7 fathoms, with two well-defined depressions. One is situated off North Head with a maximum depth of 16 fathoms, and the other off Kauri Point with 12 fathoms

The Upper Harbour lies to the westward of the Inner Harbour, and consists largely of mud flats exposed at low water. The channel runs close to the northern shore and extends for about 11½ miles past Kauri Point. The depth of the channel varies from ½ fathom to 5 fathoms. Several large tidal creeks branch off from this and are navigable for small vessels Each branch has a small fresh water stream at its head, and for this reason there should be a greater range in the salinity of this area throughout the year.

For the purposes of the Ecological Survey, the whole harbour was divided into the following areas:—

A. The Upper Harbour

B. The Inner Harbour.

C. The Motukorea Channel and the northern half of Motuihi Channel to the Harbour boundary.

D The Tamaki Passage and between Motuihi and Waiheke and the southern half of the Motuihi Channel to the Harbour boundary.

E. The Rangitoto Channel.

F The area along the northern shores of Waiheke and to the north-east of area "D."

G. The area along the northern shores of Rangitoto and Motutapu.

H. The area to the north of the area "C," including the channels and shores of Rakino and the Noises.

The areas F, G, and H form part of the waters of the Hauraki Gulf, and have been used chiefly for comparative purposes.

TIDES.

The tides in Auckland Harbour are of the semi-diurnal type and do not exhibit any general difference from similar tides in other localities.

They vary in height from 5 feet 6 inches (neaps) to 12 feet (springs). There being no great influx of fresh water, the period of ebb and flow is approximately equal, and any variation is due to wind or barometric pressure.

During January, 1933, the automatic tide gauge at Queen's Wharf showed that flood tides varied from 5 hours 58 mins. to 6 hours 46 mins., and ebb tides varied from 5 hours 34 mins. to 6 hours 32 mins. The interval between successive high waters during the same period varied from 12 hours 17 mins. to 12 hours 42 mins., and low waters from 12 hours 11 mins. to 12 hours 38 mins. No related observations of wind and air pressure were taken.

The time and height of high or low water is, of course, greatly affected by the prevailing wind. Thus at the outset of a typical cyclonic disturbance, when the wind is from the north-east and the barometer is falling, higher and earlier tides may be expected. After the centre of the disturbance has passed and the winds are westerly and the barometer is rising, lower and later tides may be expected.

The extreme difference in barometric pressure observed at Albert Park during the years 1928-31 was approximately 1 4 inches. This could account for a difference of about 1·4 feet in the height of the tides.

The prevailing winds at Auckland are westerly to south-westerly, and the ebb, therefore, should be generally rather more rapid than the flood. The maximum velocity of the tidal current is about 3 knots an hour, but varies considerably in different parts of the harbour. It is more rapid off projecting points and slower off open bays. The maximum rate recorded off the centre of Shoal Bay is 2½ knots. The maximum velocity is reached during the second hour after high water. Insufficient tests have been made to be more precise in the time of maximum. The flood-tide is rather less rapid. The tide gauge at Queen's Wharf shows that there is little period of slack water in the Inner Harbour, and the same applies to the Upper Harbour. Float tests off Motukorea Island in the Outer Harbour, however, showed no slack water at high water, but nearly two hours at low water. Problems involving tides and tidal velocities, therefore, must be dealt with according to the tidal conditions of the local areas concerned.

As would be expected, there is a greater range of tides in the Upper Harbour, the spring tides being eighteen inches greater at Riverhead than at Auckland.

An interesting series of simultaneous water level observations from Auckland to Riverhead was taken by the Harbour Board staff in 1914. The tidal wave does not become constricted until after it passes Birkdale. The tidal levels at Auckland and Birkdale show, therefore, only slight differences. Beyond this point the tide is confined through a narrow strait which leads to several long, narrow creeks. At Greenhithe, at the entrance to this narrow portion, a considerable variation is not unexpected. Again, at Lower Albany, where the tide is confined to a long, narrow channel, the rise and fall is probably greater than at Riverhead, though it is one mile nearer Auckland. Unfortunately, the water leaves the bottom of the gauge towards low water, and accurate readings are not available.

The velocity of the tidal current is also greatly increased in the Upper Harbour. A very rapid current can be observed in the narrow strait previously mentioned, but no current meter readings have been taken in this locality.

Only a general description of the course of the tidal stream can be given here. The stream enters the harbour from both entrances. That which enters by way of the Motuihi Channel is divided into two parts by Motuihi Island. The southern portion turns south and passes up the Clevedon River outside the limits of the survey. The northern portion passes up the Motukorea Channel and is divided by Motukorea Island. The southern portion passes up the Tamaki River, and the remainder goes on to meet the stream coming southward by way of Rangitoto Channel. The combined streams move in a westerly direction up the Inner Harbour. At the eastern tide deflector the stream is deflected slightly northwards towards Stokes Point, and from here follows a course rather to the north of the centre of the harbour until it enters the upper reaches. In the Upper Harbour it is confined to the deeper water and follows the course of the channel. The ebb tide follows a somewhat similar course.

It is interesting to note that the two depressions occur off projecting points of the northern shore. Similar depressions on a smaller scale occur under similar conditions in the upper reaches. Both have long been recognised as good fishing grounds, and are therefore of particular interest to the Ecological Survey.

Harbour Improvements.

The construction of two tide deflectors on the southern side of the harbour has tended to throw the tidal stream to the north of its previous course. The velocity is also somewhat increased. The deflectors appear to have made little difference to the foreshore except in Stanley Bay, where *Zostera* beds extending to the end of the wharf have disappeared and the rocky shelf on the western side of the bay is now almost completely exposed to low water level.

The area to the west of the western tide deflector is, on the other hand, silting up.

Again, by the building of the Water Front Road across the mouth of Hobson Bay, the *Zostera* beds in the area have apparently been silted up.

On the other hand, the bed from North Head towards Devonport Wharf seems to have been extended during this period. Unfortunately no previous records of the extent of the *Zostera* beds in Auckland Harbour have been made, and it is impossible to give more than an opinion on this matter. The importance of the relation of *Zostera* beds to animal life is recognised by marine biologists in other parts of the world, and a detailed survey of local areas is indicated.

Apart from the above-mentioned changes, very little difference in the contour of the harbour is shown in the various surveys taken since 1907. The difficulty of keeping a boat in exact position would easily account for the small variations which occur.

METEOROLOGICAL.

Meteorological observations have been carried out at Auckland for many years, and a summary of the previous year's observations is given in each edition of the New Zealand Official Year Book and in the Annual Reports of the Meteorological Office, Wellington.

These observations have been dealt with very fully in a series of papers and reports by the Government Meteorologist, Dr Kidson, and only a summary need be given here.

Rainfall and Humidity.

The mean annual rainfall at Auckland is 44·73 inches, occurring on an average of 175 days in the year. The precipitation is generally greatest during the months of May, June, and July. During November, December, and January, the average totals are small, but the lowest occur in December and January. The month of maximum precipitation, however, varies from year to year, and there cannot be said to be any definite " dry " and " wet " seasons.

An interesting series of observations of the incidence of rain storms of various intensities has been compiled by Mr H. H. Watkins, Engineer to the Auckland Drainage Board, covering the period 1909-30. From this has been worked out the probability of the occurrence at Auckland of rain storms of a given intensity and duration. This may be conveniently summarised as follows:—

Incidence. Times per year.	*Intensity.* Inches per hour.	*Duration* in Minutes.
6	1.5	14
5	1.5	18
4	2.0	25
3	2.0	30
2	2.5	38
1	3.0	60
1 in 2 yrs.	4.0	60

More severe storms occurring once in 4, 5, and 22 years are also recorded.

The relative humidity is high. During the years 1905-27 the monthly averages of relative humidity per cent. are as follows:—

Jan. ..	77	May ..	81	Sept. ..	80
Feb. ..	75	June ..	80	Oct. ..	79
Mar. ..	78	July ..	82	Nov. ..	79
April ..	79	Aug. ..	80	Dec. ..	77

The yearly average is 79%.

Barometric Pressure and Wind Velocity.

The yearly variation in barometric pressure is about 1·4 inches. The highest monthly averages occur in April, and the lowest in December and January, with a secondary maximum in September and a secondary minimum in June.

Wind velocities recorded by Robinson Anemometer average less than 180 miles per 24 hours. The greatest velocity ever recorded at Auckland was 947 miles per 24 hours.

The prevailing wind is south-west. The direction of the wind for the period 1865 to 1930, reduced to a percentage, is as follows:—

N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
7	16	7	7	12	28	13	10

The greatest number of days of south-westerly wind occur during the same months as the greatest average velocity, i.e., in September, October, and November. This is fully discussed by Dr Kidson in his paper on air pressure in New Zealand.

Hours of Bright Sunshine.

The average yearly total of hours of bright sunshine is 1914·5 hours. The highest monthly averages occur in January, February, and March, and the lowest in June and July.

Air Temperature.

Auckland has an average temperature of two or three degrees Fahrenheit above its expected isotherm. The daily range in temperature in the shade averages about 7·0° C., and the average yearly range is 26° C. The highest temperature recorded in the shade was 32·8° C., and the lowest —0·5° C. The mean annual temperature is approximately 14·4° C.

Sea Temperatures.

Sea temperature observations are part of the routine of the Navy, and are taken at the end of every watch, i.e., seven times a day. The observations at the Naval Depot, Devonport, were available from March, 1931. A series of monthly averages of sea temperatures at different places in the Auckland Province is given in the Annual Report on Fisheries, Marine Department, Wellington. This includes two stations in Auckland Harbour—Tamaki River and Nelson Street Wharf.

During the year 1913-14, the Auckland Harbour Board conducted a series of observations at the end of Queen's Wharf. This series was taken not more often than three times in the month, and therefore shows some irregularities. It may be said, however, that the monthly averages follow closely those given by the Fisheries Department during the years 1929-32.

No regular observations of sea temperatures are carried out in the open sea near Auckland, and the only ones available are those taken by the Fisheries Department staff at irregular intervals. None of these were taken more often than seven times in one month, and then not always at the same place. They are, however, sufficiently accurate to indicate the difference in range between the open sea and estuarine waters in approximately the same latitude.

The daily range in sea temperatures in Auckland Harbour is not great, and does not on an average exceed more than two degrees Centigrade. The daily temperature appears to reach its maximum at about 16.00 hours. This is maintained until after 18.00 hours, when it begins to fall, reaching its minimum towards 4.00 hours. As would be expected, during bright calm weather there is a sharp rise of as much as 5° C. On the other hand, during a period of heavy wind, the temperature will be depressed, irrespective of wind direction. The Naval observations show that winds of a velocity of over 4 on the Beaufort Scale may depress the temperature as much as two degrees Centrigrade.

Sea temperature observations at Auckland have been carried out for so limited a period that it is impossible to give more than an indication of the range throughout the year. It seems, however, that the temperature of the sea in Auckland Harbour follows closely the mean temperature of the surrounding land. From Table I it will be seen that there is a sudden drop in temperautres during April and May, and a sudden rise during September and October. The maximum is reached during January and February, and the minimum during July and August.

A comparison of the sea temperatures in Auckland Harbour with those of other estuarine waters and the open sea in the vicinity is given in Table II. It may be said that the more shallow the estuary, the greater will be the yearly range in temperature. During the years 1929-32 the average yearly range at the various points of observation was:—

Kaipara	11·3° C.
Tamaki	10·2° C.
Auckland	9·2° C.
Russell	7·9° C.

Of these, Kaipara is the shallowest and Russell the deepest estuary.

The open sea range for the same period was:—

Cape Brett ..	7·3° C.
Mokohinau ..	7·9° C.
Cuvier Island ..	6·5° C.

and for all open sea observations, 7·2° C.

No figures are available for the upper reaches of Auckland Harbour, but it seems reasonable to expect that the yearly range will resemble that at Tamaki or even Kaipara. It will be noted that the estuarine temperatures follow each other closely, but the open sea temperatures appear to reach their maximum a month later, i.e., during March.

Both air and sea temperatures follow closely the hours of bright sunshine, though the higher altitude of the sun during the summer months will also have an effect in increasing the temperatures.

The general increase in hours of bright sunshine, and the rise in temperatures should have some effect on the activity of the phyto-plankton during September and October, but so far no observations have been carried out to confirm this.

TABLE 1.

SEA AND AIR TEMPERATURES AND HOURS OF BRIGHT SUNSHINE AT AUCKLAND.
Temperatures in degrees Fahrenheit. Hours of Sunshine Total Hours per Month.

Month.	1929-30.			1930-31.			1931-32.		
	Sea.	Air.	Sun.	Sea.	Air.	Sun.	Sea.	Air.	Sun.
May	57.9	57.2	155.5	61.2	55.0	169.1	58.5	55.0	123.1
June	55.6	54.9	103.3	55.4	52.3	121.6	55.0	52.8	141.5
July	54.1	51.0	135.1	52.0	50.3	144.1	54.5	53.1	106.1
August	52.9	52.1	163.4	53.1	53.8	140.9	53.2	52.8	155.1
Septmbr.	57.2	53.2	146.1	55.2	53.5	147.4	55.5	53.1	175.9
October	60.1	58.0	174.8	57.4	55.3	154.3	60.1	56.4	192.1
November	63.5	61.9	147.3	59.9	58.0	178.6	66.9	63.1	220.4
December	65.8	64.4	179.4	65.1	65.5	237.3	67.1	63.7	198.5
January	65.8	66.6	223.2	68.7	66.5	213.8	69.6	65.0	268.7
February	68.4	65.8	196.9	68.4	63.0	246.7	70.7	66.7	204.8
March	68.4	64.0	253.1	67.1	62.6	195.9	69.3	65.3	188.0
April	65.1	59.6	171.5	63.7	60.9	131.2	66.6	61.8	177.8

SEWAGE DISPOSAL AND POLLUTION.

Five sewage systems discharge into Auckland Harbour. The Auckland system discharges at a point 875 feet north-east of the Orakei Jetty. Sewage is discharged during each tidal period of 6½ hours commencing 2½ hours before high water. Provision is made, however, for automatic discharge during excessive rain storms occurring during the remaining period of the tide. On Saturdays, Sundays, and public holidays the discharge is confined to night tides. Before being discharged all sewage passes through a screening apparatus of ¼ inch mesh. The soffit of the outfall sewer at the point of discharge is 22·2 feet below ordinary high water level, 14·0 feet below ordinary low water level, and 11·3 feet below the lowest recorded tide level.

The Devonport system has two outfalls. Both discharge crude sewage continuously. One outfall is situated at North Head and discharges at a depth of about six feet below L.W.S.T. The other outfall is off the southern end of Narrow Neck Beach and discharges into Rangitoto Channel at a point about 9 feet below L.W.S.T.

The Takapuna system has also two outfalls. Both discharge crude sewage from storage tanks. The northern outfall discharges

TABLE ... NTIGRADE.

							R			Ka			Cape Brett.			Mokohinau					
May	14.4	6.2	4.7	15.8	.2	4.1	16.6	16.7	5.4		14.5	5.1	6.0	8.3	6.2	5.5	8.5	7.0	4.7	8.5	7.1
June	13.1	13.0	12.8	12.8	1.9	11.9	15.0	14.4	14.1		13.3	2.4	4.3	5.7	4.7	14.5	6.5	6.0	13.7	4.5	15.5
July	12.8	11.1	12.5	10.8	0.3	11.3	11.8	14.5	13.2	1.9	12.4	1.2	1.5	4.6	3.5	13.2	4.0	—	14.0	4.5	—
Aug.	11.6	11.7	11.8	12.2	1.2	11.4	12.7	14.3	12.2	1.7	12.3	2.2	4.0	5.0	2.0	10.7	4.0	3.5	12.0	4.5	14.0
Sept.	14.0	12.9	13.0	13.6	3.2	13.2	15.0	14.4	13.1	3.6	14.2	3.6	5.2	4.7	3.2	17.0	5.5	4.0	17.5	4.5	13.7
Oct.	15.6	14.1	15.6	15.5	4.8	15.9	17.0	15.5	14.7	5.4	15.0	3.8	7.5	4.7	5.5	13.0	5.0	4.0	14.0	5.0	15.0
Nov.	17.5	15.5	19.4	18.1	.6.8	20.8	18.3	16.2	17.1	7.3	15.7	9.5	6.7	6.2	6.5	16.7	4.7	—	16.0	4.5	16.3
Dec.	18.8	18.4	19.5	19.0	20.1	19.6	19.2	17.7	18.2	.9.7	20.4	21.6	7.2	8.9	6.6	18.5	6.1	7.3	17.7	5.6	17.3
Jan.	18.8	20.4	20.9	19.8	21.0	21.2	19.0	20.8	20.8	21.1	23.4	23.0	7.6	0.5	7.7	18.5	9.0	8.2	18.5	9.5	18.0
Feb.	20.2	20.2	21.5	20.8	20.1	20.8	19.5	19.7	19.7	21.6	21.2	23.7	9.3	9.7	.9.1	18.2	8.0	9.1	19.5	8.0	18.5
Mar.	20.2	19.5	20.7	20.1	19.3	20.4	20.4	19.1	19.1	22.0	19.2	20.2	9.9	9.5	8.5	20.5		21.0	20.4	7.8	20.0
Apl.	18.4	17.6	19.2	17.4	17.1	19.1	19.0	17.6	17.6	19.4	19.0	18.5	9.0	7.7	8.0	18.9		20.0	18.5	8.5	20.0

into Rangitoto Channel at Black Rock near Milford Beach. The storage tanks at this point can hold 360,000 gallons, and at present sewage is discharged every second day. The point of discharge is 12 feet below L.W.S.T. The southern outfall also discharges into Rangitoto Channel at a point off St. Leonard's Road to the south of Takapuna Beach. The storage tanks at this point have a capacity of 250,000 gallons, and sewage is discharged at present every fourth day. The point of discharge is 6 feet below L.W.S.T.

Details of the sewage systems in the Northcote and Otahuhu districts are not available. They are, however, smaller than the other systems, and an approximate amount of daily discharge has been estimated on a population basis. In both cases a septic tank system is installed and only the effluent is discharged. The amount of pollution from these two sources is probably negligible, but the estimated daily amounts have been included in the total for the whole harbour.

During wet weather, the sewage discharge is greatly increased and a large amount of storm water flows direct into the harbour. A certain amount of crude sewage is also discharged from vessels in the port. These details have not been considered in the following table.

District.	Method of Disposal.	Daily Average Discharge in Gallons.
Auckland and Suburban	Screened sewage from Orakei Outfall for 6½ hours every tide commencing 2½ hours before high water.	14,500,000
Devonport	Crude sewage discharging continuously from one outfall at North Head and one outfall Rangitoto Channel.	400,000
Takapuna	Crude sewage discharged from storage tanks every second day. Two outfalls in Rangitoto Channel.	130,000
Northcote	One outfall at Stokes Point. Septic tanks with tidal discharge of effluent.	70,000*
Otahuhu	Two outfalls into Tamaki River. Septic tanks with effluent discharging continuously.	100,000*
	Total	15,200,000

* Estimated on a population basis.

Sewage pollution of harbour waters has been the subject of much discussion, and from time to time statements are made of the serious deterioration of animal life from this cause. The recent work in Copenhagen Sound by Blegvad and Aage, however, shows that the effect of sewage pollution on the fauna and flora of estuaries has been somewhat exaggerated. If any serious deterioration has taken place, it must be pointed out that this is more likely to be due to general harbour improvements than to sewage pollution.

It has been estimated that approximately 254,560,000 gallons of tidal water per minute pass over a line drawn from Orakei Wharf to the old wharf at Devonport, i.e., roughly north from Auckland sewer outfall. From the above table it will be seen that sufficient tidal water passes over this line in one minute to dilute the average daily discharge of sewage into Auckland Harbour more than sixteen times. There can be no doubt of the complete dilution of this discharge over two tidal periods of 12½ hours each.

The author has been unable to detect any difference in salinity and hydrogen ion concentration between samples taken near the Orakei outfall and those from other parts of the harbour.

A series of analyses carried out on February 2nd, 1929, by Mr K. M. Griffin for the Auckland Drainage Board, gave the following results:—

Sample.	1 Between Orakei Outfall and Beacon Rock at 10.45 a.m.	2 Off Bastion Beacon and edge of discharge fan south side at 10.55 a.m.	3 Outside edge of discharge fan off North Head at 11.5 a.m	4 In flow of sewage 150 yards from outfall.
Smell at 100° F.	Faint	Faint	Faint	Faint
Chlorinity ..	1988.0	1959.6	1995.1	1988.0
Nitrogen as Nitrates.	Nil	Nil	Nil	Nil
Nitrogen as Nitrites.	Nil	Nil	Nil	Nil
Ammoniacal nitrogen from free and saline ammonia.	0.0010	0.0145	0.0015	0.0012
Albuminoid nitrogen.	0.0060	0.0110	0.0075	0.0100
Oxygen absorbed in 4 hrs. at 80° F.	0.0370	0.0480	0.0400	0.0400

Results expressed in parts per 100,000.

All four samples are rather cloudy in appearance, and on standing gave large deposits. One or two organisms other than normal diatoms were detected.

The free ammonia in No. 2 is high and indicates a fair amount of pollution by sewage, but the other three samples are normal harbour water.

Bacteriological examination gave the following results:—

Sample No. 1.—Sample slightly turbid and colourless. Earthy matter and infusoria present in deposit. B. Coli present in 1·0 c.c. No. of colonies on Agar at 37 deg. C. 15 per c.c.

Sample No. 2.—Sample somewhat turbid and yellowish. Earthy matter and many bacteria in deposit. B. Coli present in 0·1 c.c. No. of colonies on Agar at 37 deg. C. 93 per c.c.

Sample No. 3.—Sample slightly turbid and colourless. Earthy matter in deposit. B. Coli present in 0·2 c.c. No. of colonies on Agar at 37 deg. C. 58 per c.c.

Sample No. 4.—Sample slightly turbid and colourless. Earthy matter and infusoria in deposit. B. Coli present in 0·1 c.c. No. of colonies on Agar at 37 deg. C. 106 per c.c.

High water was at 8.20 a.m., and all samples were taken whilst the Orakei storage tanks were discharging.

Other chemical analyses gave the following results:—

Sample.	A. Middle of Harbour off Stanley Bay.	B. 1½ miles below Riverhead.	C. Rangitoto Channel during sewage discharge.	D. Orakei Outfall during discharge.
Free Ammonia	0.0014	0.0020	0.0016	0.1840
Alb. Ammonia	0.0070	0.0116	0.0078	0.0320
Oxygen absorbed	0.0320	0.1250	0.0420	0.1100

Sample D is very high in free ammonia and albuminoid ammonia, showing the presence of sewage.

Sample B contains more organic matter than is normally present in sea water and is also lower in salinity. The sample probably represents the normal water of this part of the Auckland Harbour, and these features are no doubt due to the intermixing with fresh water from streams in the vicinity.

It will be seen that with the exception of Sample D taken immediately above the sewer outfall at Orakei, all samples are normal estuarine waters. It must be remembered, however, that bacterial pollution of the harbour is possible from decaying animal and vegetable matter on the foreshore and from the washings of agricultural lands, streets, etc., during wet weather, and care should be taken with regard to the consumption of edible shellfish and similar marine animals in the Inner Harbour area.

Pelagic animals such as fish will probably avoid highly polluted areas and are unlikely to be disturbed by the present amount of sewage discharge.

Chemical Composition of Harbour Waters.

The information available is practically negative. Nothing has been done with the exception of two chlorinity determinations by Phillips and Grigg (1925).

The analyses conducted by Griffin for the Health Department are unsuitable for biological or hydrographical purposes. Further, the samples had obviously been stored for some time previous to

analysis, with the result that the salinity figures are too high and the supply of nitrates used up by the microplankton present. Similar results in salinity were obtained from stored samples collected by the Survey Staff, and these have been rejected.

In the limited time at his disposal, the author has carried out a small number of salinity and hydrogen ion determinations. Unfortunately, equipment is not available to carry out the salinity tests by the method of Oxner and Knudsen (1920), and the determinations were made volumetrically by titrating with silver nitrate solution standardised against pure sodium chloride using potassium chromate as an indicator. The results are, therefore, approximate only.

The hydrogen ion determinations were carried out in the field by means of a "B.D.H." colorimetric set using cresol red as an indicator.

No determinations have been made of the water in the Upper Harbour, but it is to be expected there will be a considerable amount of variation in the salinity of this area throughout the year. No details are available to show the effect of rain on the salinity and hydrogen ion concentration of the water or to show how long it takes the water to return to normal. Further, no determinations have been made of the seasonal variations in the nitrate, phosphate, and oxygen content. This work would entail the full time services of a hydrologist, and such is not at present available in Auckland.

In Table III the two observations of Phillips and Grigg, collected in 1923, have been placed at the head, and for convenience have been converted to total salinity figures by Knudsen's formula $S\text{o/oo} = 0{\cdot}030 + 1{\cdot}8050\ \mathrm{Cl}$.

TABLE III.

SALINITY AND HYDROGEN ION CONCENTRATION OF SEA WATER AT AUCKLAND

Date.	Temp. °C.	Sal. *o/oo*	pH.	Locality.	Time
5/9/23	—	34.95	—	Inner Harbour	—
5/9/23	—	35.26	—	Queen's Wharf	—
6/12/32	16.9	34.87	8.30	Hobson Bay	9.10 a.m.
,,	17.4	35.00	8.25	Off Orakei Wharf	9.20 a.m.
,,	17.2	34.90	8.20	Between Rangitoto Wharf and Tamaki	9.40 a.m.
,,	17.0	35.00	8.40	Off Emu Point, Motutapu	10.5 a.m.
,,	17.1	35.22	8.30	Between Motutapu and Waiheke	10.30 a.m.
,,	16.5	35.25	8.24	David Rocks, Noises Islands	11.20 a.m.
14/12/32	18.0	34.52	8.26	Queen's Wharf	8.30 a.m.
,,	18.5	35.00	8.29	North Head	9.50 a.m.
,,	18.75	35.10	8.34	Rangitoto Beacon	10.15 a.m.
,,	19.00	35.12	8.33	Between Rangitoto and Tiri Tiri	10.45 a.m.
,,	21.00	35.13	8.27	Tiri Tiri Island Wharf	11.40 a.m.
7/4/33	19.75	35.00	8.32	Rosaria Channel, Kawau	9.15 a.m.
,,	20.25	35.09	8.37	Off West Coast of Moturoa Island	11.40 a.m.
,,	20.00	34.90	8.37	Whangaparaoa Passage	1.00 p.m.
,,	20.25	34.95	8.33	Between Tiri Tiri and Rangitoto	4.5 p.m.
,,	20.00	34.90	8.33	Rangitoto Beacon	4.50 p.m.

Summary.

From the data at present available it would be unwise to state any definite conclusions. It is apparent, however, that the Auckland Harbour does not differ greatly from similar areas in other parts of the world, and it may, in fact, be described as a typical tidal estuary.

The hydrographical features vary considerably in different parts of the harbour, and this fact must be taken into consideration when the ecological details of a particular area are being worked out.

The temperature in Auckland Harbour is 2° or 3° F. above its expected isotherm.

The sea temperatures follow closely the air temperatures, and both follow the hours of bright sunshine.

There is a rapid rise in sea temperatures during September and October and a corresponding fall in April and May.

The present amount of sewage entering the harbour should be insufficient to cause serious pollution of the water, and apart from possible bacterial infection of mollusca, is not a serious menace.

The improvement schemes of recent years have destroyed several areas of *Zostera*, and this may have some effect on the biological features of the harbour.

The salinity and hydrogen ion concentration determinations show a close similarity to related observations in other places.

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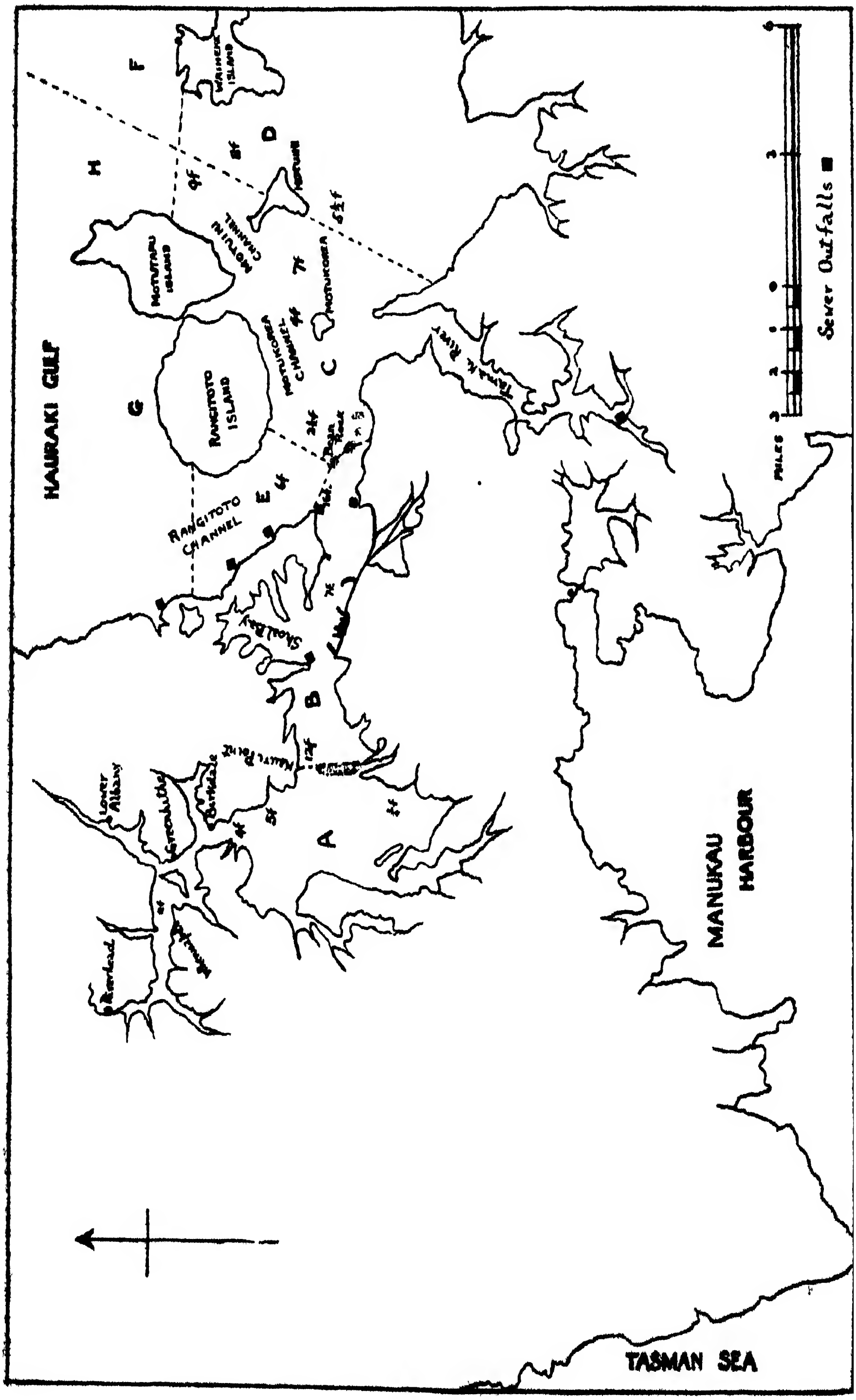
DESCRIPTION OF TEXT FIGURES.

1. Map of Auckland and Vicinity showing Harbour Survey Areas and Sewer Outfalls.

2. Graph showing Relation of Sea and Air Temperatures and Hours of Bright Sunshine at Auckland.

3. Graph showing the Relation of Sea Temperatures at Auckland, Kaipara, and Cape Brett.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MOTUTAPU ISLAND
MOTUKOREA CHANNEL
MOTUKOREA
MOTUIHI CHANNEL
WAIHEKE ISLAND
Shoal Bay
Tamaki River
Lower Albany
Birkdale
MANUKAU HARBOUR
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MILES
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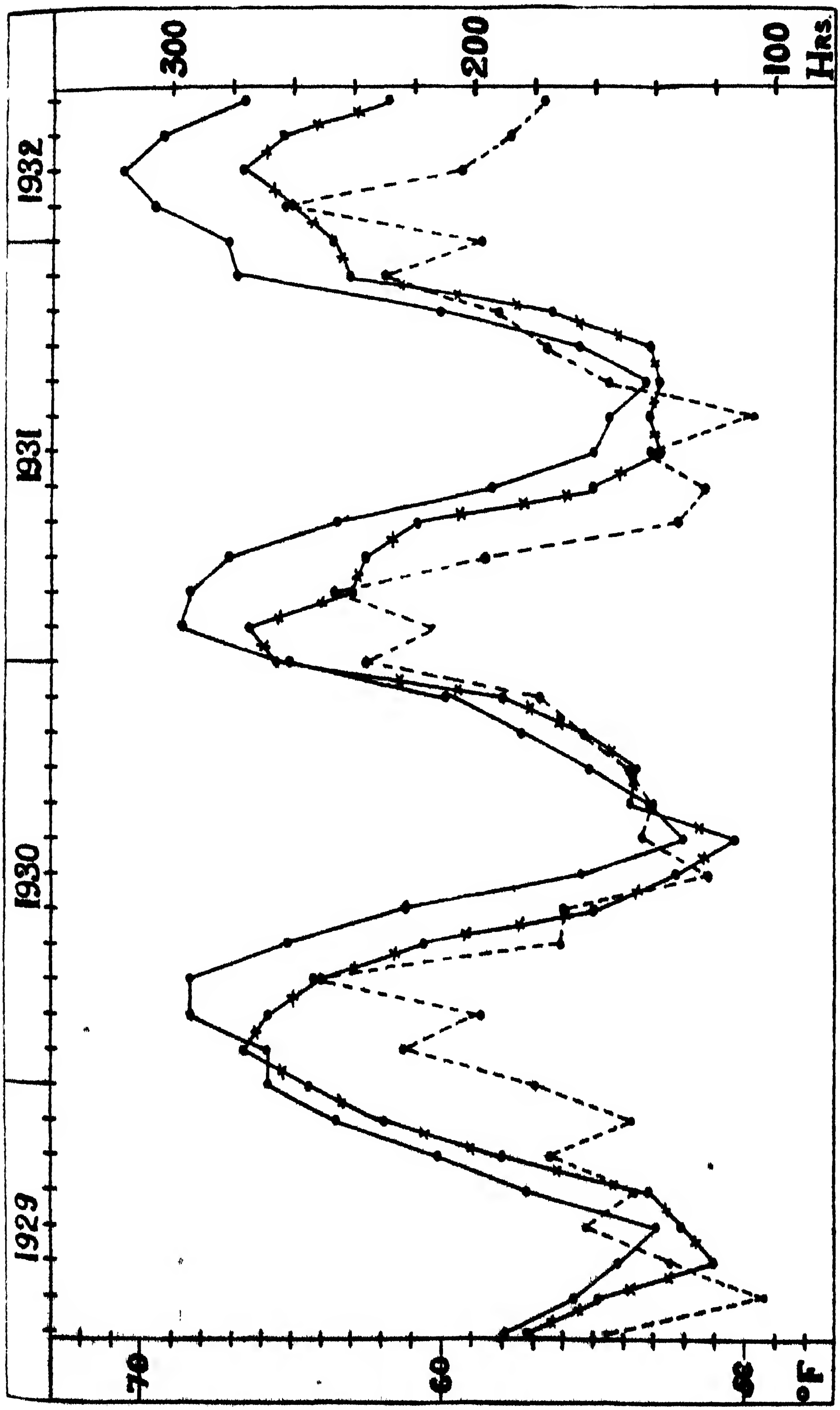
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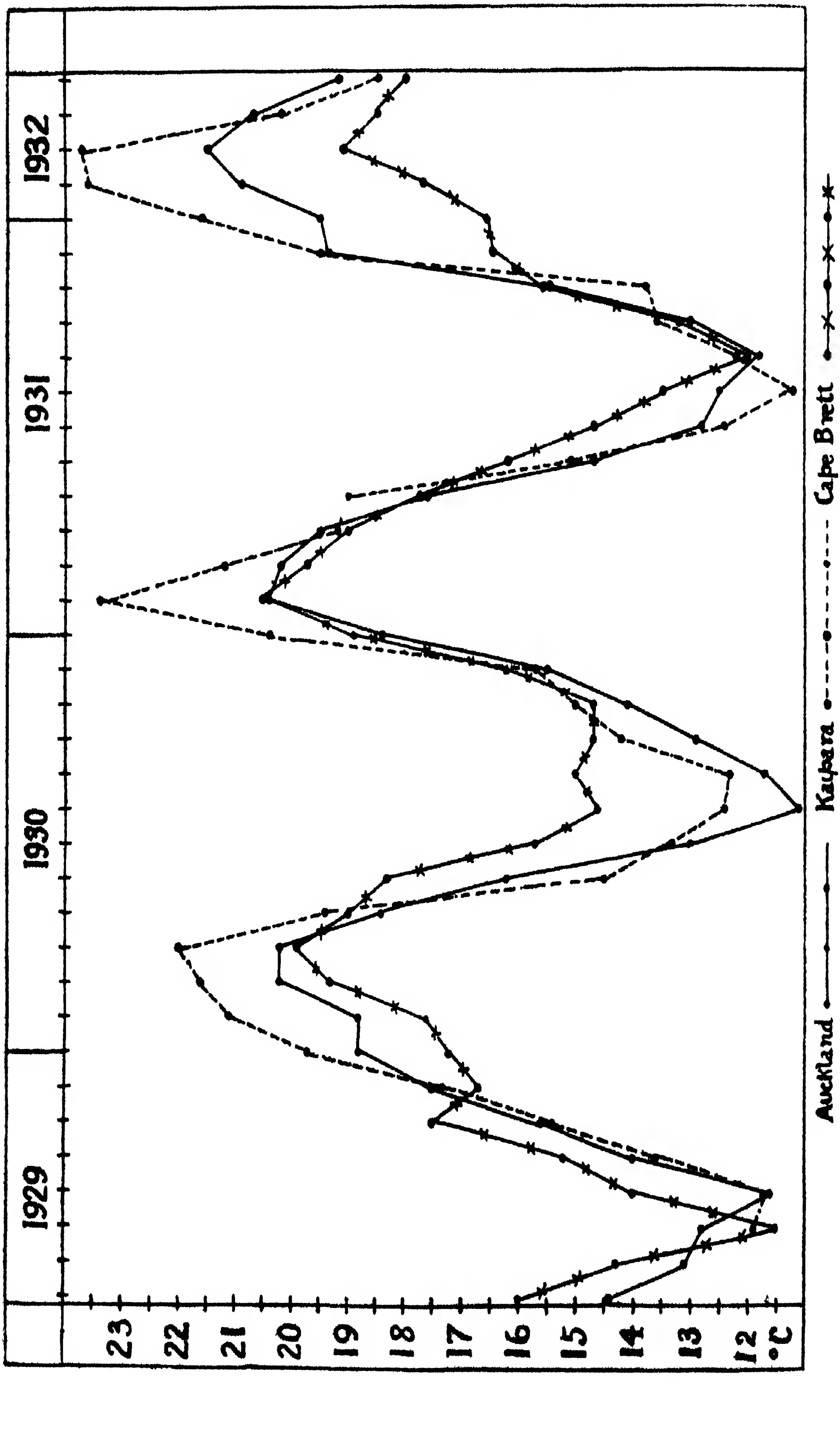
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The Geology of the Glenomaru Survey District, Otago, New Zealand.

By J. B. MACKIE, M.Sc., A.O.S.M.,

Lubecki Research Scholar, University of Otago.

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CONTENTS.

INTRODUCTION.

THE district described comprises an area of some 40 square miles, lying on the east coast of the South Island of New Zealand, about 80 miles south of Dunedin, Otago. The township of Owaka lies in the south-western portion of the area, in a fairly extensive and low-lying basin through which meanders the Owaka River. Until comparatively recent years the whole district, except the lower-lying parts, was covered with dense beech and pine forests, and although most of these have now been removed by the local sawmillers, the slopes of the higher ridges and some of the more isolated areas still remain in their natural wooded state.

The field work was carried out in the earlier part of 1932, and comprised both the geological mapping and the contouring of the whole area. Some good sections were obtained both in the railway cuttings and on the coast, the one in Roaring (Shaw) Bay being especially noteworthy, as it is the classical exposure of the Triassic sediments in New Zealand.

The petrographic section of this paper deals almost exclusively with the pebbles from the Triassic and Jurassic conglomerates, but the writer hopes to submit for publication shortly an account, with several analyses, of the greywackes and slates occurring in the area.

PREVIOUS WORK.

W. L. Lindsay, as early as 1862 (p 30), examined the rocks immediately south-west of Nugget Point, and recognised their Triassic age, while Alexander McKay, in 1873, also collected fossils at this and other localities throughout the area. Two years later F. W. Hutton placed the beds at Roaring Bay in the Maitai formation, which he considered to be of Triassic age; the rocks between Roaring Bay and Cannibal Bay he included in the Putataka formation, to which he assigned a Lower Jurassic age. In 1903 Professor Park and Mr A. Hamilton visited the coastal section, and the former investigator in the following year published a detailed section of the Roaring Bay sequence, and a generalised section of the coast from Kaka Point (5 miles north of Nugget Point) to the mouth of the Catlins River (5 miles south-west of Nugget Point). He also listed and described the fossils which he collected during this visit.

Professor R. Speight, in 1904, described the dyke which cuts across the neck of land between Nugget Point promontory and the mainland.

The most recent work carried out in this district was that of Dr C. T. Trechmann, who collected and gave detailed descriptions of fossils from Roaring Bay (Trechmann, 1917). As a result of his palaeontological work he was able to subdivide the Triassic sequence, and to indicate that the Noric beds were missing at this locality, though he remarked that Dr Marshall had found the fossil characteristic of this series (*Pseudomonotis*) at Glenomaru, 7½ miles from the coast. Dr Otto Wilckens later (1927) amplified Trechmann's work to some extent by detailed descriptions of the fossil collections from Roaring Bay made by Park and Hamilton in 1903 for the Geological Survey. In 1923 Dr Trechmann also described a few Jurassic fossils collected by Dr Marshall from the beds between Roaring and Cannibal Bays. Some fossil plants from near Owaka, which had been obtained partly by Hector in 1865 and partly by A. McKay in 1873, were described by Dr E. A. N. Arber (1917), who, with hesitation, assigned to them a Rhaetic (?) or Lower Jurassic (?) age.

Marshall (1912) and Cotton (1922) both comment upon the curious pattern of the drainage system of the area.

It will be seen, therefore, that the greater part of the work carried out in the Glenomaru Survey District has been confined to the more exposed coastal regions. The discovery of the plant fossils, and of the *Pseudomonotis* beds at Glenomaru is all that is available from the inland area.

SUMMARY OF GENERAL GEOLOGY.

The majority of the rocks occurring throughout the area are of Triassic and Jurassic age, although locally these are covered by a superficial veneer of Recent dune sands and alluvium. In the north-eastern half are steeply dipping Triassic and Jurassic members, and in the south-western, gently flexed Jurassic strata.

A survey of the coastline, which in the main cuts directly across the general direction of strike, reveals beds of age decreasing southwards from Campbell's Point. The Triassic system comes to an end near the south head of Roaring Bay, and all the contorted strata south-west of this point are Jurassic. The Recent deposits occur in the form of patches of alluvium and sand which make up river and coastal flats.

The Mesozoic rocks consist, for the most part, of a thick series of greywackes, felspathic sandstones, claystones, conglomerates, etc., whose hardness and compactness indicate that they have suffered considerable pressure. These rocks were deposited probably under deltaic, estuarine, or near-shore conditions. During the great Hokonui (Closing Jurassic-Lower Cretaceous) Orogeny they were strongly folded and were later reduced by erosion to a peneplain state before the close of Cretaceous times. It is probable that, in common with the rest of the East-coastal region of the South Island of New Zealand, the present district was covered by marine sediments during the late Cretaceous and Tertiary Eras. All traces of these younger beds have, however, been removed by subsequent erosion from the area here described, though they remain to the north (Wangaloa), north-west (Chatton), and west (Southland).

The present topography doubtless evolved subsequently to the uplift experienced in Pliocene and early Pleistocene times during the Kaikoura Orogeny of Cotton (1916, p. 248). Still later warping probably accounts for the Owaka "basin" or "depression," and the formation of the swamps connected therewith.

The most recent movement was a minor uplift, evidence of which exists in the form of raised beaches, much as in other parts of the East Coast district of Otago.

SUMMARY OF STRATIGRAPHY.

The oldest rocks exposed in the area are in the north-eastern portion. Although fossils occur in them, they are so poorly preserved and fragmentary that they give no reliable indication of age, but apparently they belong to the Middle Triassic. The rocks of Nugget Point itself are placed by Dr Trechmann (1917) in the Middle Triassic (?), so that in the absence of faulting, those to the north-east must therefore be older, and may thus possibly extend into the Lower Triassic. They consist for the most part of hard, fairly coarse-grained greywackes, with interbedded finer-grained fossiliferous claystones and a conglomerate.

The beds recognised by Trechmann (1917, p. 180) as Ladino-Carnic, comprising greywackes, sandstones, and claystones, are the oldest beds whose age has been definitely recognised, and they are observed to best advantage on the coast in the extreme north of Roaring Bay, and in the Nugget Point Peninsula. They are followed by some 2000 feet of greywackes, conglomerates, sandstones, and claystones, whose fairly abundant fossil fauna establishes their age as Carnic. These are most clearly exposed in the cliffs about Roaring Bay, and are seen at various points further inland, where they are recognisable particularly by their massive conglomerates.

The marine Noric beds, which appear to thin out and disappear towards the coast, are represented near Glenomaru Railway Station by gritty, pebbly sandstones and interbedded mudstones, both of which are abundantly fossiliferous in places. It is probable that they are represented on the coast by a disconformity.

The Triassic deposits are brought to a close by about 200 feet of fossiliferous, pebbly sandstones and indurated claystones, the latter bearing indeterminate plant remains. With no sign of unconformity, these Rhaetic beds pass up into the Jurassic sequence which continues in an unbroken succession of greywackes, sandstones, mudstones, and conglomerates—all with an extremely high dip—for about 14,000 feet. Fossils, which are fairly plentiful at several stages, allow no doubt of their Jurassic age.

There is then a great gap in the succession, for the next deposits are of Recent age.

It is interesting to note that at no stage in this extensive sequence of strata is there any sign of contemporaneous igneous activity. The only outcrop of massive igneous rock in the whole area is that of the dyke of porphyry at Nugget Point, which is intrusive into the Triassic rocks. The conglomerates, however, include numerous igneous pebbles—mostly of intrusive rock types, but also including volcanic forms—indicating the existence in Triassic and Jurassic times of a batholithic mass uncovered by erosion.

DETAILED STRATIGRAPHY.

Although outcrops are fairly plentiful throughout the area, the general stratigraphical succession is revealed to best advantage on the coast. Therefore, in the following pages the coastal section will be reviewed in detail, and supplemented by information gained inland.

A.—THE COASTAL SUCCESSION.

1. *The Middle Triassic System.*—The lowest member of this series forms conspicuous outcrops in an anticline exposed on the coast at Campbell's Point, extending seaward as an expanse of low-lying, jagged reefs. Their strike is well-marked, but variable, and it can be seen to veer through twenty or thirty degrees within a distance as small as twenty yards. At this point the rocks are banded, consisting of alternating layers of coarse and fine-grained greywacke-grits. The coarser rock often contains tiny pebbles of greywacke, claystone, and a reddish, jasperoid material. Sea-erosion has removed some of the less-resistant rock in many places so that the harder layers only now remain.

These pass up into a softer, fine-grained claystone. Outcrops of this are sparse, and the beach is more or less clear of reefs for some 600ft. (indicating a thickness of 560ft.) until we come upon another outcrop of hard, coarse-grained greywacke-grit, 140ft. thick.

The next member of the series is a comparatively soft, fine-grained, dark-grey claystone, which is, in general, traversed by numerous small joints. Outcrops occur at various points on the

beach, followed southward to within about 5 chains of Hay's Gap. Occasionally there are traces of fossils in this rock and among these a form like *Daonella* seems to be predominant. Other forms, if present, are indeterminate. At the point where Nugget Creek crosses the beach these fossiliferous claystones are interrupted by a resistant conglomerate 16ft. wide, which weathers to a rusty-red colour and forms a well-marked outcrop. The largest pebble observed was about 11 inches in diameter. The cementing medium is exceedingly hard; the pebbles include both igneous and sedimentary rocks, the latter being mainly greywacke, claystone, or silicified mudstone.

Five chains north of Hay's Gap are further hard and relatively coarse-grained greywacke-grits, which, followed through the Gap itself, become laminated, and are interbedded with thin bands of softer rock. The bands are often cemented with ferruginous material which stands out in thin layers from the rest of the rock as was noted by Park (1904, p. 380).

Following on these immediately to the south of Hay's Gap promontory there is a thickness of about 200ft. of jointed dark-grey fossiliferous claystone containing a *Daonella* (?), and similar to that mentioned above. This gives way, higher in the sequence, to more coarse-grained indurated sandstones which are often interbedded with softer rock. Fourteen chains south of Hay's Gap is the centre of a syncline occurring in the harder beds, followed by an anticline five chains further south. From this point onwards the Middle Triassic Beds dip to the south-west at angles varying from 45 to 90 degrees, with some variation in strike, which is here nearly parallel to the coast. Professor Park (1904, p. 380) comments concerning this part of the sequence: "Towards the Nuggets the sandstones become coarser in texture, and in places assume the character of greywacke. They form high, rocky points and numerous isolated flat reefs on the beach below high-water mark, separated by stretches of sand." Seventeen chains north-west from the Fishing Station is a layer of dark-grey claystone, about 7-8 feet thick, in which was found a *Spiriferina*.

The highest member of the Middle Triassic is a greyish claystone containing abundant plant remains, none of which, unfortunately, are determinable. This bed, which is about 200ft. thick, forms the core of the Nugget Point peninsula, and the lighthouse itself stands upon it.

At the point where the track leading to the lighthouse leaves the beach near Boatlanding Bay, there is a thin bed of fossiliferous claystone. The only definite form recognised here by the writer was a badly preserved *Spiriferina*. Professor Park, however, notes the following from this locality: Three species of *Spiriferina, Epithyris, Rhynchonella, Pleurotomaria,* and fragments of a bivalve shell resembling *Modiolopsis* (1904, p. 381). Indefinite fossils also occur in the sandstones underlying this bed.

The most noteworthy feature of the Middle Triassic beds is their marked variation in dip and strike. An attempt was made to trace the Campbell's Bay conglomerate inland, but after about a

quarter of a mile it was obscured by the dense bush. The section along Nugget Creek road is a disappointing one, for there are only a few poor outcrops of weathered sandstone, making any correlation with the coastal beds impossible. From the variation in the strike and dip it appears certain that some wedging of the strata occurs.

The total estimated thickness of Middle Trias deposits in this locality is 5200ft.

2. *The Ladino-Carnic, Carnic, and Rhaetic Series.*—These three series are best considered under one heading, since they all outcrop in a compact sequence making up Roaring Bay. The section across the bay was described in 1904 by Professor Park, and the present writer can do no more than quote his sequence and measurements (also confirmed by Dr. C. T. Trechmann in 1917).

Following conformably upon the Middle Triassic plant-bearing claystones we have, proceeding southwards*:—

17-18	a. Indurated sandstone and greywacke, 150ft. b. *Spiriferina* beds—dark-blue claystones, 100ft.
16	c. Porphyry dyke
	d Greywacke.
15-14	e. Fossiliferous, crumbling claystones with *Halobia zitteli*. About 210ft. thick. Seen in the road cutting descending to the bay.
	f. Sandstones and claystones, 250ft., not exposed on beach.
13	g. Breccia-conglomerate, angle of dip 77deg., 20ft.
12	h. Highly indurated claystones, 55ft.
11	i. Hard greywacke, 15ft.
10	j. Thinly laminated claystones and sandstones, 24ft.
9	k. Breccia-conglomerate, slaty and granitic, 27ft.
8	l. Gritty sandstone, 15ft. m. Indurated sandstones with occasional beds of claystone, 200ft., nearly vertical.
7	n. Granitic conglomerate, 10 inches thick; angle of dip 86 deg.
6	o. Indurated claystone, 50ft. p. *Myophoria* bed—claystones, 10ft. Contains an ammonoid shell, *Myophoria nuggetensis, Pleurotomaria,* and other Carnic fossils.
5	q. Sandstones and claystones with subordinate bands of gritty sandstone, 450ft.
4	r. *Mytilus problematicus* bed, 29ft.; angle of dip 78 deg.
3	s. Coarse sandstones with occasional gravel layers, 600ft.
2	t. *Clavigera* beds, 10ft.—sandstone containing *Clavigera bisulcata* and *Spiriferina diomedea.*
1	u. Plant beds—sandstones and claystones.

* The numbering corresponds as far as possible with that on Trechmann's section; the lettering with Park's Divisions. For diagrammatic section see Trechmann, 1917, p. 180

There are three layers containing *Clavigera bisulcata*, separated by beds of barren sandstone, the sequence in ascending order being:—

Dark-blue indurated claystones—at the base.
Bed of granitic conglomerate 4in thick.
Clavigera bed, 40in., very fossiliferous.
Sandstone, 4ft.
Clavigera bed, 2ft.
Sandstone, 4ft.
Clavigera bed, 18in.
Indurated sandstones and claystones.

The upper *Clavigera* bed is a coarse, gritty, often pebbly, sandstone containing such an abundance of *Clavigera* and *Spiriferina* valves that the rock is in places moderately calcareous. At the south head of Roaring Bay, the strata are nearly vertical, and the lower *Clavigera* bed stands up like a wall, presenting an even surface 70ft. high and 100ft. long, thickly encrusted with *Clavigera* and *Spiriferina* shells which have weathered out of the matrix.

In the above list of beds a. and b. (18-17) have been referred to the Ladino-Carnic age. The beds d. to s. (15-3) are considered to be Carnic, while the remainder are classed as Rhaetic. Nowhere is there any indication in this succession of the Noric beds characterised by *Pseudomonotis*, which are well developed at Glenomaru. It is therefore to be inferred that a non-sequence or disconformity exists between beds s. and t. (3 and 2).

The lists of fossils determining the ages of the series are given below:—

LADINO-CARNIC (Beds a. and b. or 18-17).

LAMELLIBRANCHIATA:—

**Daonella indica* Bittner.

BRACHIOPODA:—

**Halorella zealandica* Trechm.
**Dielasma cf. himalayana* Bittner. ?
†*Dielasma cf. zealandica* Trechm.
**Spiriferina fragilis* Schlotheim.
**Mentzeliopsis spinosa* Trechm. ?

CARNIC (Beds d. to s. or 15-3).

CEPHALOPODA:—

**Grypoceras cf. mesodiscum* Hauer.
**Proclydonautilus mandevillei* (Marshall).
**Discophyllites cf. ohneri* Mojsisovics.

GASTEROPODA:—

**Pleurotomaria (Sisenna) hectori* Trechm.
†*Trochus (Tectus) marshalli* Trechm.
**Bourguetia (?) arata* Trechm.

* Species noted by Trechmann.
† Additional species noted by Wilckens.

LAMELLIBRANCHIATA :—

**Halobia zitteli* Lindstrom var. zealandica.
**Myalina (?) (Maoria) problematica* (Zitt.) ("Mytilus problematicus").
**Hokonuia rotundata* Trechm.
**Pecten* sp.
†*Nuggetia morganiana* Wilck.
**Anodontophora edmondiiformis* Trechm.
**Myophoria nuggetensis* Trechm.
**Palaeocardita quadrata* Trechm.
†*Gonodon mellingi* Hauer.

BRACHIOPODA :—

†*Spirigera cf. wreyi.*
Rhynchonella (Halorella) cf. griesbachi Bittner.

Only a few of these species could be obtained from the rocks at present exposed in Roaring Bay. According to the writer's collecting, they were zonally distributed throughout the Carnic as follows:—

BEDS :—	d	e	p	r
Pleurotomaria (Sisenna) hectori ..			x	
Halobia zitteli		x		
Myalina ? problematica				x
Myophoria nuggetensis			x	
Gonodon mellingi				x
Rhynchonella cf. griesbachi		x		

RHAETIC (Beds t. and u. or 2-1).

BRACHIOPODA :—

Clavigera (Hectoria) bisulcata Trechm.
Spiriferina diomedea Trechm.
Spiriferina sp.

The grounds on which Trechmann assigns a Rhaetic age to these beds are the similarity of *Clavigera bisulcata* to *Spirigera oxycolpos* of the Alpine Trias, but more especially the fact that elsewhere in New Zealand, viz., near Kawhia, in the North Island, *C. bisulcata* and *S. diomedea* are associated with a form compared with the Alpine Rhaetic fossil *Arcestes rhaeticus* Clark and lie upon the Noric beds with *Pseudomonotis*.

In addition to the above lists Wilckens notes the presence of:—

Rhynchonella nuggetensis
Rhynchonella maorica
Spiriferina parki

in the Halobia and Spiriferina beds (AA) of Park, which includes both the Ladino-Carnic and Lower Carnic.

The total estimated thickness of Ladino-Carnic, Carnic, and Rhaetic is 3200ft.

* Species noted by Trechmann.
† Additional species noted by Wilckens.

3. *The Jurassic System.*—The Jurassic system is assumed to commence at the southern side of the south head of Roaring Bay in a vertical, coarse, felspathic sandstone (J_1) with pebbles of both igneous and sedimentary rocks sometimes up to nearly 2in. diameter. As it increases in thickness, this sandstone becomes less pebbly and more finely grained, frequently weathering to a rust-red colour, due to a ferruginous cement. The total thickness is about 250-260ft.

The next 1050ft. of strata (J_2) consist of claystones and slaty mudstones interbedded near the base with fine-grained ferruginous sandstone, and near the top with layers of hard greywacke. Five chains north-east of the mouth of the creek flowing into the northern side of Sandy Bay is a hard, indurated sandstone (J_3) 460ft. thick, which at the creek-mouth itself becomes concretionary in places, and also shows a well-developed series of joints. The concretions measure up to 6in. or 7in. in diameter.

Above this comes an extensive thickness—some 2000ft.—of claystones and indurated mudstones (J_4). About 330ft. from their base there is an extremely fossiliferous band extending, with interbedded barren claystones, through 30ft., and consisting in its richest parts, almost entirely of the compressed and distorted valves of the lamellibranch *Pseudaucella marshalli* (first obtained here by Dr P. Marshall). Solution of the carbonate of the shells has caused both the bed and the neighbouring rock to be traversed by numerous calcite veins. One chain south of the mouth of the main Sandy Bay Creek the claystone becomes laminated and interbedded with occasional layers of hard, crystalline, fine-grained greywacke. Bands of sandstone with indeterminate plant (?) remains come in higher in the sequence, while the uppermost 260ft. has numerous greywacke layers. Slight bending of the strata is also in evidence in this upper part.

Concerning the age of this *Pseudaucella* claystone (J_4), it may be noted that the fossil originally doubtfully described by Trechmann (1923, p. 269) as *Aucella marshalli*, was also found by Marshall near Kawhia harbour (North Island, New Zealand) in a similarly crowded shell-band 1000-1500ft. above the top of the Triassic Sequence as recognised in that district, a view since confirmed by the Geological Survey. Dr. Marwick (1924, p. 305) created for the species a new genus *Pseudaucella*, and considered it marked a zone of middle Liassic age (Henderson and Grange, 1926, p. 37).

The next member (J_5) is a hard, relatively coarse, indurated sandstone, concretionary in places, which forms the south side of Sandy Bay. One hundred and ten feet from its base is a thin layer of conglomerate containing a variety of pebbles both of igneous and sedimentary rocks, ranging in size up to 8in. long by 2½in. wide. The pebbles of the latter class are usually fine-grained—argillite, greywacke, indurated mudstone, etc. The greatest width of the conglomerate is about 11in., but it is very variable, thinning out altogether at points within a few yards of one another.

The first little bay to the south of Sandy Bay (Bay A) is excavated in a rather soft, banded, and more or less concretionary

sandstone with occasional pebbles (J_6). On the south side of this bay hard sandstone (J_7) is again encountered which shows well-developed honeycomb-weathering. Between Bay A and Boatlanding Bay the sandstone is fine-grained and banded, being composed of alternating thin layers differing slightly in colour and grain size.

Extending across Boatlanding Bay (330ft.) is an indurated and jointed, banded claystone (J_8), in which the sea, on the south side of the bay, has worn flat pavements. There are traces of fossils here, but nothing definite was recognised. McKay (1873) collected fossils at this locality, but unfortunately he did not give their names. Near the southern shore of Boatlanding Bay the claystone becomes sandy and concretionary, finally passing up into indurated banded felspathic sandstone (J_9) which shows honeycomb weathering. This sandstone forms the headland between Boatlanding Bay and Bay B, but on the northern side of the latter it passes into a conglomerate which is possibly 6ft. thick, and which contains igneous and sedimentary pebbles up to 2in. diameter The rock within Bay B itself is an indurated greenish sandy mudstone (J_{10}) 120ft. thick. It is interbedded with hard, sometimes pebbly sandstone, and is succeeded by 60-70ft. of pebbly felspathic sandstone (J_{11}) forming the small promontory between Bay B and Tuck's Bay.

On the northern side of Tuck's Bay a greenish-grey, slightly indurated mudstone of small thickness comes in, followed by a dark-grey friable claystone (J_{12}) which continues to the south side of the bay, where it gives way to a hard, jointed sandstone (J_{13}) interbedded with crystalline greywacke. These rocks, with occasional pebbly and felspathic layers, continue to the northern shore of Cannibal Bay, where there is a fossiliferous claystone (J_{14}) containing *Trigonia, Ostrea, Anomia, Inoceramus, Pholadomya, Venus* (Park 1904, p. 386), and Ammonites and Belemnites (McKay, 1873, p. 72). In spite of careful searching the writer was unable to obtain all the above forms, but succeeded in finding a number of slightly distorted shells resembling very closely the *Aucella spitiensis* cf. var. *extensa* Holdhaus described and figured by Trechmann (1923, p. 267) from the Upper Jurassic of Waikato, South Heads, North Island, New Zealand.

The claystones at the north shore of Cannibal Bay are only about 150ft. thick (dip 87° S), and they are the last or uppermost of the continuous coastal sequence. The structure and lithology of the remaining beds (Jurassic) are well revealed by inland outcrops, and at one other point on the coast, viz., False Islet.

The above-mentioned claystones (with *Aucella* cf. *spitiensis*) are replaced within a few chains by a greenish, banded mudstone which continues to the southern margin of Cannibal Bay. The bed is interstratified near the middle with harder, impersistent layers of pebbly felspathic grit, causing it to stand out as a low ridge throughout its whole extent. (N.B.—These Cannibal Bay mudstones and claystones, together with the grit, are included under J_{14}).

At the south side of Cannibal Bay, on False Islet, an indurated sandstone (J_{15}) forms a steep slope just over the summit of which are bands of felspathic sandstone containing many pebbles of quartz-

ite, sandstone, jasperoid slate, silicified mudstone, and various igneous rocks. The dip at this point is 85° south. The pebbles are present through a thickness of about 145ft., and in some places are in such abundance as to warrant the term conglomerate. About the centre of the Islet the dip changes to the northward, whereby the sandstones and pebbly layers are repeated to the south (see Section E-F). The southern end of the Islet is traversed by a fault which repeats the pebbly layers and brings into view the underlying sandstones. The dip here is 45° north.

The total estimated thickness of Jurassic sequence is 13,800ft.

B.—NOTES ON THE INLAND OCCURRENCES.

The geological map (Plate 51) attached hereto indicates the general distribution of the various members in the sequence. The accompanying block diagram (Text Fig. II) was drawn in an attempt to demonstrate how the more resistent strata can be followed inland as well-marked ridges separated by valleys excavated in the softer rocks.

With regard to the Noric series, it may be noted that although no bed to which a definite Noric age can be assigned occurs in the Roaring Bay section, coarse, pebbly, felspathic grits, with thin mudstone layers, both, especially the latter, containing thickly crowded specimens of *Pseudomonotis richmondiana* Trechm., are found about 6½ miles inland, directly along the line of strike from the southern part of Roaring Bay. The fossils were found on a ridge, 35 chains south-east of Trig. E, and according to Dr. Marshall (personal communication to Dr. Benson) they also occur on the steep banks of the Glenomaru Stream, 30 chains north-east of Glenomaru Railway Station. Local residents state that they may be found between these two points.

It is not clear what thickness may be assigned to the Noric beds near Glenomaru; the fossiliferous band itself is only a few feet thick, but the pebbly felspathic grits extend through 1550-1650ft. Whether or not the latter represent the whole of the Noric sequence here cannot definitely be stated. The pebbly felspathic grits have been traced to within 2¼ miles of the coast, but then are obscured by bush. Nearer the coast no exactly similar beds could be recognised.

Fifty-two chains east of Trig. E, on Wright's "Harakeke" Farm, outcrops of fossiliferous mudstone contain the following characteristic New Zealand Carnic forms in a fair state of preservation:—

GASTEROPOD:—
Pleurotomaria (?)

LAMELLIBRANCHIATA:—
Anodontophora edmondiiformis
Anodontophora ovalis
Gonodon cf. mellingi Hauer as of Wilck.

BRACHIOPOD:—
Spirigera wreyi

Careful searching revealed no rocks containing the characteristic Roaring Bay Rhaetic fossils, viz., *Clavigera bisulcata* and *Spiriferina diomedea*, but beds of similar lithology could be traced at isolated localities for about two miles inland.

Fossiliferous Localities in the Jurassic Sequence:—

1. Sandy Bay. Bed J_4.

   Pseudaucella marshalli......Mid. Lias.

2. Seventy-six chains north-west of locality 1. above. Bed J_4.

   Pseudaucella marshalli......Mid. Lias.

3. Fifty-four chains south-west of Trig. II, on hillside. Base J_9.

   Aucella (?)

4. Three-quarters of a mile north-west of Tuck's Bay in roadside quarry. Top J_9.

   Pseudomonotis cf. echinata Sowerby....Lower Oolite (Trechm., 1923, p. 271)

   Inoceramus haasti
   Inoceramus labiatus Schloth. } Park, 1904, p. 385.
   Pecten

5. Two miles thirty-two chains north-west of Boatlanding Bay (between Sandy Bay and Tuck's Bay) in quarry reserve. J_8.

   An ammonite
   Pinna
   Arca } Park, 1904, p. 385.
   Panopaea
   Pholadomya

6. Boatlanding Bay (between Sandy Bay and Tuck's Bay). J_8. No forms recognisable. McKay's collection (1873) unnamed.

7. North side of Cannibal Bay. J_{14}.

   Aucella cf. spitiensis......Upper Jurassic (?)
   Trigonia
   Ostrea
   Anomia
   Inoceramus } Park, 1904, p. 386.
   Pholadomya
   Venus

   Ammonites
   Belemnites } McKay, 1873, p. 72.

8. North end of Bridge over Catlins River, in quarry. J_{14}. No recognisable forms.

9. In Owaka River bank at main-road bridge. Upper J_{14}. Plants obtained by McKay (1873, p. 61) and Hector (1865) and described by Arber (1917, p. 10).

With some hesitation Arber assigns the age of these beds to the Rhaetic (?), noting that they may be either Rhaetic (?) or Lower Jurassic (?). He states that he is inclined to favour a Rhaetic age on account of the abundance of *Thinnfeldia* (1917, p. 11).

On the evidence of the faunas obtained in lower Jurassic strata, this plant bed must at least be younger than Middle Liassic, or than Lower Oolite if the *Pseudomonotis cf. echinata* gives a reliable age indication. The presence of *Aucella cf. spitiensis* in the lower part of this plant-bearing band, indicating an Upper Jurassic age, is an apparent contradiction to the evidence offered by the plants, since *Thinnfeldia* appears to be very scarce even in the Middle Jurassic of New Zealand (Arber, 1917).

At present, on account of the weighty evidence afforded by the plants, the writer must place the J_{14} mudstones in the Lower Oolite.

The beds J_1 to J_4 are included in the Liassic Series, while J_4 to J_{15} are assigned to the Lower Oolite.

Total Thickness of Triassic and Jurassic Systems.—The total thickness of the Mid. Trias, Ladino-Carnic, Carnic, Noric, Rhaetic, and Jurassic beds (allowing 1000ft. for the Noric) is 23,000ft. This appears an abnormal thickness, but there are no major faults to account for it by repetition of beds. Henderson and Grange (1926, p. 31) note that the thickness of Triassic and Jurassic strata exposed in the Huntly-Kawhia district is 28,000ft. (the rocks described by them as Lower Cretaceous have now been proved to be Upper Jurassic).

Recent Deposits.—These are purely superficial and occur locally as thin layers of sand and alluvium as well as sand dunes. McKay (1873, p. 61) states that he collected moa bones from the sandspit at the mouth of the Catlins River, while local residents informed the writer that quite a number of Maori skeletons had been found in the sand at the back of False Islet. Recent raised beach sands and conglomerates are described later among the coastal features.

N.B.—Ongley (1933) has mapped and described the continuation of the Trias-Jura rocks to the north-west of the area at present under consideration.

PETROLOGY.

A.—DETAILED DESCRIPTIONS OF PEBBLES FROM CONGLOMERATES.

All percentage estimations and measurements in the following descriptions have been made by eye only, except where otherwise noted. The determinations of felspar compositions are according to the methods and charts of Winchell (1927, pp. 277-341).

1. *Middle (?) Triassic Conglomerate at Mouth of Nugget Creek.*

Nos. 2119, 2121. *Quartz-mica-diorites.* Hypidiomorphic; average grain-size, 1-1¼ mm. The felspar (70%) is usually more or less prismatic, with albite twinning general. Combinations of carlsbad and albite twins are occasionally seen. Almost every crystal is zoned, the composition of the outermost layers being about $Ab_{88}An_{12}$ and that of the kernels about $Ab_{60}An_{40}$. There is very little orthoclase

present. Decomposition to kaolin and sericite is taking place more in the cores of the felspars than at the edges. Quartz (15-20%) forms clear, irregular (interstitial) crystals which show very slight straining. The biotite (5%) is pleochroic from pale golden yellow to fairly deep reddish-brown, and occurs as ragged aggregates and little flakes which frequently show incipient chloritisation. Accessories include a few grains of magnetite and plentiful needles and little prisms of apatite.

Nos. 2120, 2122, 2123. *Quartz-porphyrites* (perhaps with trondhjemitic affinities). Holocrystalline; porphyritic. The phenocrysts (which range in length up to 2½ mm.) consist of quartz, felspar, and chlorite, the latter being pseudomorphous after some original ferromagnesian mineral. A number of the quartz crystals have been corroded by the magma and show rounded outlines and inlets of the groundmass. There are also perfectly idiomorphic quartz crystals which have not suffered corrosion. The felspar, being fairly decomposed, was difficult to determine, and gave a variety of compositions where determinations were possible. However, from the presence of zoning in some of the crystals it was concluded that the composition varied from $Ab_{70}An_{30}$ to about $Ab_{84}An_{16}$. The felspars, as well as the quartz, exhibit corrosion phenomena. Albite twinning is fairly common, and the decomposition product is kaolin. Chlorite is now all that remains of former ferromagnesians. It is usually a fibrous variety with negative elongation and a double refraction of 0·004 to 0·005. The pleochroic scheme is: Y = Z = green; X = light yellowish green; absorption is Y = Z>X. The clear octagonal and hexagonal outlines of some of the pseudomorphs, however, reveal that the original mafic minerals were probably augite and hornblende. The percentage of the ferromagnesians was not great (about 5%). Biotite may have been present. Accessories include sphene, apatite, and iron ore. The apatite is sometimes distinctly dichroic from pale brownish-purple to pale bluish-grey. The groundmass is very finely crystalline and indeterminate.

No. 2124. Very fine-grained, indeterminate base in which are set a few small angular quartz and decomposed felspar fragments and grains of iron ore. The hand-specimen is greenish yellow and very hard; it is probably a *silicified mudstone.*

No. 2125. *Conglomerate matrix.* The section shows very decomposed angular and broken fragments of felspar and quartz measuring up to 1 mm. in diameter, set in a fine quartzose and muddy ground. One felspar indicated a composition about oligoclase-andesine, while another showed distinct zoning. Embedded here and there in the section are more or less rounded pieces of exceedingly fine-grained sedimentary rocks, and one small mass of carbonaceous matter.

2. *Lowest Carnic Conglomerate of Roaring Bay.*

No. 2106. *Granite Pegmatite.* Micropegmatitic; the plagioclase (15-20%) is allotriomorphic and frequently shows zoning ($Ab_{88}An_{12}$ to $Ab_{70}An_{30}$). The crystals reach 3½ mm. in diameter and are all twinned on the albite law, a few exhibiting pericline or carlsbad twinning in addition. Decomposition is progressing more rapidly in

the centres of the plagioclases. Orthoclase (50-55%) occurs both as large crystals up to 2½ mm. diameter and in micrographic intergrowth with quartz. The larger crystals sometimes show subidiomorphic outlines, and in one or two cases the margins of these can be seen passing into the intergrowth. The orthoclase is decomposing generally to sericite and kaolin, but granules of epidote as well were observed in the plagioclase. Quartz, usually somewhat strained, reaches 20-25%, while biotite, commonly altered to masses of chlorite, quartz, epidote, and magnetite makes up about 5% of the section. Iron ore (1%) and apatite are accessories. About 40% of the rock consists of a coarse micrographic intergrowth of quartz and orthoclase.

No 2107. *Mica porphyrite.* Macroscopically the rock is fine-grained, brown in colour, with green felspar phenocrysts. The thin section is holocrystalline and porphyritic, the phenocrysts reaching 2½ mm. in diameter. The felspar phenocrysts are usually decomposed, and often dotted with bright green spots and clusters of chloritic matter. The general decomposition product appears to be kaolin Albite lamellation is almost universal in the phenocrysts, carlsbad twinning being also occasionally seen. In one part of the section there is a glomeroporphyritic mass of felspar crystals up to 2 mm. in diameter with an occasional chloritised biotite crystal, and interstitial groundmass. The felspars in this patch are subidiomorphic tabular to more or less elongated. Long needles of apatite are scattered abundantly throughout the felspars in the cluster. As a rule the felspars are somewhat zoned, the kernels being medium andesine and the outer layer about $Ab_{75}An_{25}$. The biotite (5%) occurs in idiomorphic to subidiomorphic flakes up to 1 mm. long. Pleochroism is from light golden-brown to very dark brown. In every case the crystal is decomposing round the edges to a mixture of little chlorite flakes and grains of magnetite. In some cases the biotite has gone over completely to chlorite and magnetite. Magnetite occurs in irregular and rounded grains up to 0·4 mm. They are fairly abundant throughout the section. Idiomorphic crystals of apatite and zircon also occur. The groundmass is microcrystalline and indeterminate; it apparently consists of felspar and quartz, chloritic and ferritic matter, the latter giving the whole a brownish tinge.

No. 2108. *Albitised (?) quartz dolerite.* Holocrystalline. The section is composed mainly of felspar laths and tables set at all angles, the interstices being filled by smaller felspar laths and tables together with quartz, grains of epidote, sphene, and shapeless pieces of chlorite. There are occasional grains of magnetite also. The felspar (60%) has an average composition about $Ab_{91}An_{9}$. The lathy form predominates over the tabular. Albite twinning is common, but combinations of albite and carlsbad twins are also frequently seen. Some of the crystals have started to decompose to kaolin dust, while others appear to have been more or less epidotised. The maximum length of the felspar laths is 1·25 mm. The quartz (10%) fills up the spaces between the felspar laths, where it frequently forms a kind of poecilitic background in which are set the smaller felspar laths and tables, epidote grains, etc. The chlorite (10-15%)

is usually the light green variety, although occasionally yellowish green also, this latter type appearing fibrous between crossed nicols. The double refraction of the epidote varies even in a single crystal from very weak to strong, thus indicating a variation in the Fe_2O_3 content. Probably all members of the range clinozoisite to epidote are present. The colour varies from colourless to very pale yellowish-green. Plentiful small irregular grains of sphene can be distinguished from the epidote by their higher refractive index and double refraction. The magnetite occurs as small broken fragments invariably surrounded by chlorite.

Nos. 2109, 2110. *Partially crushed hornblende-granite.* Average grain-size in the less crushed parts is about 1-1¼ mm., but much finer in the more crushed portions. Some of the plagioclase is zoned slightly, the average composition being about medium oligoclase. The orthoclase (15%) is generally untwinned. Quartz makes up about 20% of the section, but most of it has been crushed and is very often streaked out into bands, giving the rock a somewhat gneissic appearance, while porphyroclastic structure is well demonstrated in places. The mafic minerals include streaked-out aggregates of little twisted biotites (12-15%), and small, broken hornblendes (3%). A litle chlorite is being produced by decomposition of the biotite and hornblende. Accessories include ilmenite in small grains and aggregates, sometimes in radiating clusters of little needles; sphene in grains up to 0·3 mm.; and small prisms and needles of apatite.

No. 2111. *Granophyre.* The specimen was very decomposed, and the section consists mostly of a fine micrographic intergrowth of quartz and very much altered orthoclase, in which are set occasional twinned crystals of plagioclase (oligoclase ?), clusters of iron ore (ilmenite?), and patches of green chloritic matter. In places the intergrowth is very regular.

3. *Second Carnic Conglomerate, Roaring Bay.*

This conglomerate is made up of much smaller pebbles than the other conglomerates of the area, with the result that each of the chips collected for sectioning contained a variety of rock types.

No. 2113. Rounded to subangular fragments of the following are all present in this section.

- (a) *Vesicular basaltic glass* containing a few "swallow-tailed" felspar microlites, with green chloritic matter and quartz in the vesicles.
- (b) *Coarse dolerite* made up of felspar laths with plentiful chloritic matter in the interstices.
- (c) *Andesitic* or *trachytic* fragments; felspar laths show fluxional arrangement.
- (d) *Rhyolite;* groundmass appears to be devitrified, from its extremely microcrystalline state.
- (e) *Greywacke.*
- (f) *Slate.*
- (g) *Granitoid rock (Trondhjemite).* Cf. No. 2094.

No. 2114. Pebbles of:—

(a) Carbonaceous shale.
(b) Fine-grained slaty material.
(c) Banded rhyolite (?).
(d) Vesicular basalt glass.
(e) Fine-grained greywacke.

The matrix is similar to that of No. 2113.

Nos. 2115, 2116, 2117, contain pebbles similar to Nos. 2113 and 2114, and No. 2118 is composed almost entirely of a pebble which resembles very closely that of (g), No. 2113, except that the porphyroclasts do not reach such a large size.

4. "*Granite*" *Conglomerate, Roaring Bay.*

No. 2094. *Soda-rich granite,* or *Trondhjemite.* Hypidiomorphic; average grain-size about 1½-2 mm. The felspar, which makes up the bulk of the rock, is generally very decomposed, and often kaolinisation renders determination difficult. By far the most abundant felspar is oligoclase ($Ab_{80}An_{20}$). One small patch of a vermicular intergrowth of plagioclase and quartz was noted. There is about 5-10% of orthoclase, the exact amount being indefinite on account of decomposition products, but there can be no doubt that it is very subordinate. Quartz (20-25%) occurs in comparatively clear grains up to 2 mm. diameter. It is typically without crystal boundaries and usually has lines of minute inclusions which are often curved. It frequently shows undulose extinction. Small crystals of apatite and biotite are sometimes enclosed. The biotite, of which there is only about 5%, occurs as irregular flakes, and sometimes as subidiomorphic plates. The mineral is strongly pleochroic, the colour ranging from a very pale straw-yellow to a deep reddish-brown. A peculiar feature is an intergrowth with quartz (Text Fig. 1). The latter mineral seems mainly to be in lines parallel to the cleavages of the biotite. Magnetite dust is often present along the cleavage cracks in the mica. Zircon can be distinguished by the pleochroic haloes surrounding it, in the biotite; one of these was 0·053 mm. in radius. Apatite, and magnetite with a limonitic decomposition product, are common accessories. Calcite forms isolated and irregular patches, and may either be derived from decomposition of the felspars or introduced by percolating solutions.

No. 2095. *Trondhjemite.* Cf. No. 2094.

No. 2098. *Trondhjemite.* Coarse grained variety (crystals up to 3½ mm.). The percentage estimations in this section were made with the aid of a Shand's recording micrometer. See table, p. ... The plagioclase is more sodic than in the previous two rocks ($Ab_{91}An_9$ to $Ab_{89}An_{11}$).

Four other trondhjemitic rocks were described from this conglomerate, the mineral composition in each case being essentially the same as in the preceding descriptions. No. 2097, however, differs in that its characteristic feature is the recrystallisation of the quartz which now takes the form of a granular mass of interlocking allotrio-

morphic crystals, demonstrating well the "sutured" structure so common in some hornfelses. The felspar in this rock is oligoclase ($Ab_{84}An_{16}$), and accessories comprise zircon, sphene, and iron ore. Some parts of the section are almost gneissic in appearance. No. 2105 is a trondhjemitic pegmatite whose felspar, albite-oligoclase, often forms large crystals up to 6 mm. diameter.

Other pebbles sectioned include two *porphyrites* Nos. 2096 and 2103, the latter being very decomposed, but appearing to have dacitic affinities.

No. 2096. Holocrystalline; porphyritic.

Phenocrysts.—The only phenocrysts are of plagioclase. These reach 1·25 mm. in diameter and are very numerous. Usually sharply idiomorphic in outline, they are, as a rule, strongly zoned. Their composition in the centres is $An_{45}Ab_{55}$, but on the borders it is about $An_{24}Ab_{76}$.

Groundmass.—In some parts of the section this might be described as having the orthophyric structure, since there are often numerous litle stout felspar prisms arranged haphazardly amongst finer felspar needles. However, the structure appears to vary in different parts. It usually consists of small felspar needles without any definite arrangement, interspersed with which are little crystals of iron ore and patches of indefinite chloritic substance which is probably the result of alteration of former ferromagnesians.

A greywacke, No. 2104, also listed from this conglomerate, contained shell fragments resembling polyzoons, while the matrix in which the pebbles were bedded (No. 2100) revealed small sections of crinoid (?) stems and a few fragments of felspar with a composition as basic as andesine-labradorite.

5. *Triassic Conglomerate near Clinton, Otago.*

Professor W. N. Benson kindly allowed the writer to section and describe a number of rocks which were collected by him from the Triassic (Carnic) conglomerates near Clinton, 74 miles south-west from Dunedin. The collection includes No. 2126, a potash-granite or pegmatite; Nos. 2127 and 2128, quartz-biotite-felspar-gneisses; and Nos. 2129, 2130, 2131, 2132, and 2133, quartz-mica-diorites. Descriptions of Nos. 2127 and 2129 are appended, each being fully representative of its group. The potash-granite is quite a normal member of that family.

No. 2127. *Quartz-biotite-felspar gneiss.* Allotriomorphic; average grain-size = about ·7 mm. The felspar, which forms 50% of the rock, has a composition about $An_{25}Ab_{75}$. There is probably 10-15% of orthoclase present. Twinning is not a very common feature of the felspars, but the crystals frequently show alteration to kaolin, and very occasionally to tiny flakes of sericite. The crystal boundaries are not well defined, the quartz and felspar forming a more or less coarse-grained mosaic in which are set numerous biotite flakes. Slight zoning is shown by some of the plagioclase crystals, while others exhibit undulose extinction. Quartz (25-30%) occurs as clear

allotriomorphic grains which commonly show undulose extinction. The biotite, which is very abundant in this rock (20%), usually has irregular outlines and occurs in crystals up to 1 mm. long. The pleochroism is from a pale yellow to a deep reddish-brown, one or two of the crystals showing lamellar twinning. Small inclusions of zircon must be fairly plentiful, as indicated by the numerous pleochroic haloes, the largest of which was 0 04 mm. in radius. A small amount of greenish chloritic matter is present, and accessories include muscovite, magnetite, and zircon; the muscovite appears to be primary—fringing the biotites in places; the magnetite forms a few little isolated grains.

Both the hand specimen and section indicate that the rock is a recrystallisation product, the former being a comparatively fine-grained, light-coloured rock whose surface sparkles due to the numerous little biotite flakes. Banding is not very obvious in the hand-specimen.

No. 2129 *Quartz-mica-diorite.* Hypidiomorphic; average grain-size = 1½-2 mm. The felspar is seen often in fairly large, sub-idiomorphic crystals which are sometimes tabular and sometimes prismatic. Quite often they exhibit zoning, the interior being oligoclase-andesine or acid andesine, and the outermost layer having the composition $Ab_{73}An_{27}$. Albite-lamellation is almost universal, but twins of the carlsbad type are seen only in a few cases. Decomposition products include both kaolin and sericite. A small amount (1-2%) orthoclase was observed. The quartz (15%) frequently shows undulose extinction; it is interstitial and usually has numbers of small inclusions and bubbles. Hornblende, though present to the extent of only 5% in the section, is shown by the hand-specimen to be much more plentiful (20-15%). The crystals do not generally show good outlines, and the size (in the hand specimen) ranges up to 5 mm. in length. The pleochroism is: Z = deep green. Y = dark olive green. X = light yellowish green. Absorption $Z > Y > X$.

Occurring as inclusions in the hornblende are small round spots of quartz, and some litle grains of magnetite. The biotite, of which there is some 5-10% in the hand specimen is pleochroic from light yellow to dark brown, and sometimes shows incipient chloritisation. Magnetite dust is occasionally to be seen along the cleavage cracks, and sometimes the cleavages themselves show slight twisting. The iron-ore occurs as little grains of magnetite. Apatite occurs sparsely in little grains and prisms. The biotite and hornblende are occasionally intergrown. The hand-specimen is a light-coloured rock showing quartz, felspar, and black ferromagnesians. It is rather coarse-grained.

6. *Conglomerate on South Side of Sandy Bay (Jurassic).*

No. 2141. *Aplite.* (Allotriomorphic). The rock consists of an equigranular (average grain-size about 0·2 mm.) aggregate of quartz and felspar (orthoclase) scattered throughout which are larger quartz grains (up to 3 mm.) and subidiomorphic prismatic crystals of felspar

(up to 2½ mm.). These latter include plagioclase, commonly zoned from basic albite $Ab_{91}An_9$ to basic oligoclase $Ab_{73}An_{27}$, a few crystals of microperthite, and one or two of orthoclase. The larger felspars are decomposing to kaolin dust and sericite flakes, being generally quite clouded, while the alteration of the felspar in the granular aggregate has not advanced so far. The majority of the quartz shows slight straining. There is about 10% of green chloritic material occurring as wisps and subidiomorphic flakes (with negative elongation) replacing original biotite, some of which has not entirely disappeared. Other minerals present are magnetite grains, epidote grains (often associated with the chlorite), a few little apatite needles and prisms, and a number of small zircons, which, when they occur in the biotite, are surrounded by the characteristic pleochroic haloes. There is probably 30% of felspar (plagioclase predominating over orthoclase) and 5% of quartz occurring as larger crystals, the granular aggregate making up about 55% of the section. Of this aggregate 45% is orthoclase, about 10-20% albite, and the remainder quartz; the magnetite, apatite, epidote, and zircon make up perhaps 2%

The hand specimen is a fine-grained granitic-looking rock, carrying occasional large pinkish crystals of non-striated felspar in a greyish crystalline matrix speckled with darker (chloritised) biotites.

No. 2150. *Aplite* The same in structure and minerals as No. 2141. The grain-size, however, is smaller in general, that of the granular aggregate being about 0 075 mm., while there appears to be more orthoclase among the larger crystals, and less biotite. The largest felspar is 4 mm. long and 0 3 mm. wide.

No. 2144. *Albitised quartz-dolerite.* This rock, though a good deal finer grained, is very similar in structure and mineral content to section No. 2108 of Conglomerate No. 2 above.

No. 2145. *Ceratophyre.* Porphyritic. Phenocrysts: A few idiomorphic crystals (up to 1 mm.) of felspar, most of which is twinned albite ($Ab_{95}An_5$), but some of which is orthoclase. These are all dusted with fine decomposition products, and sometimes show chlorite as an alteration. Other phenocrysts include a small number of fairly large crystals of apatite (up to 0·3 mm. long by 0·04 mm. wide) which all show dichroism from brown to dark brown. Irregular patches of epidote, chlorite, and calcite are scattered throughout the section. An outstanding feature is the presence of vesicles, filled with secondary material, the largest of which is about 5½ mm. long. The shape is generally irregularly ovoid to rounded, and the filling is mostly epidote in groups of radiating crystals with the centres of radiation situated at the margin of the vesicle. Each vesicle has a narrow border of chlorite, and the epidote is sometimes associated with grains of quartz. The groundmass, throughout which are interspersed small pieces of epidote, sphene, and chloritic matter, with perhaps a little opaque iron ore, is fine grained and is composed of little lath-like felspars showing a frequent tendency to trachytic structure.

7. *Conglomerate on North Side of Bay B (Jurassic).*

No. 2140. *Trondhjemite.*

No. 2139. *Granite.* Allotriomorphic; average grain-size about 1½ mm.

Felspar { Acid oligoclase ($Ab_{89}An_{11}$) 20-25%
Orthoclase 50%

The felspar is all more or less decomposed—the orthoclase perhaps more so than the plagioclase. The latter generally has albite twin lamellation, whereas the orthoclase shows only an occasional carlsbad twin. Quartz is fairly abundant (25%) and has very slight undulose extinction. Accessories: A few small scraps of chloritised biotite, and a grain or two of magnetite.

8. *Pebbly Sandstone on North Side of False Islet (Jurassic).*

No. 2134. *Sediment.* The section contains:—

(a) A fragment of very decomposed rock made up of epidotised felspar prisms whose average size is 1½ mm. long by 0 3 mm. broad set in an indeterminate base.

(b) A piece of much-altered volcanic rock composed of little felspar laths (acid andesine ?) with fluxional arrangement, plentiful magnetite grains, and chloritic matter with an occasional larger, zoned felspar (andesite ?).

The rest of the rock contains abundant felspar fragments of all sizes and shapes up to 1½ mm., but usually a good deal smaller than this. The most basic felspar seen had the composition of basic oligoclase. Quartz does not seem to be very plentiful. Magnetite occurs as grains and streaks of dust, epidote as moderately abundant grains, and chlorite as little shreds.

All the above are set in a fine-grained, muddy, indeterminate base.

No. 2135. *Granite Pegmatite.* Cf. No. 2106.

No. 2137. *Porphyrite.* Sections consist of phenocrysts of quartz and oligoclase (probably $Ab_{88}An_{12}$) set in a very fine-grained quartzo-felspathic groundmass in which are little imperfectly radiate aggregates of felspar resembling spherulites. The felspar phenocrysts are nearly all twinned on the albite law, and are very much decomposed to sericite and kaolin. The quartz shows rounded outlines and inlets of the groundmass, and remains clear. There are pseudomorphs of chloritic matter after some original ferromagnesian mineral (hornblende and perhaps biotite).

Note.—A number of pebbles of granite, diorite, porphyrite, and porphyry, apparently very similar to some of the types noted above, have been described by Dr. P. Marshall (1903) from the Triassic conglomerates of Nelson, New Zealand.

No. 2160. *Dyke, Nugget Point.* Although a number of sections from this dyke were cut and examined, the writer has nothing to add to the very complete description given by Professor Speight in 1904. The rock is a *felspar porphyry*, the hand specimen being a

dark grey, fine-grained rock containing numerous conspicuous phenocrysts of white felspar.

B.—GENERAL REMARKS ON THE NATURE OF THE PEBBLES.

Several outstanding features are revealed in the detailed petrographic investigation of the Mesozoic conglomerates:—

(a) The majority of the igneous rocks examined are of acid composition, and include granites, trondhjemites, pegmatites, granophyres, quartz- and mica-porphyrites, quartz-mica-diorites, rhyolitic and andesitic rocks, albite dolerites, and a ceratophyre.

(b) Many of these rocks are highly sodic, e.g., trondhjemites, albite dolerites, and ceratophyre.*

Amongst the most interesting of the above rock-types are the *trondhjemites* or sodic granites. Goldschmidt, who proposed the name for the group, gives a definition (1916, p. 76) which may be translated as follows: "I define the trondhjemite as a leucrocratic acid plutonic rock whose essential light-coloured constituents are a sodium-rich plagioclase (of the oligoclase or andesine series) and quartz, while potassic felspar is almost entirely absent, or plays a very subordinate role. Among the most sparing, often very sparing, dark minerals, biotite is the most important, though in a smaller division its place is sometimes taken by amphibole (rarely) or even more rarely by a diopside pyroxene."

All the trondhjemites described from the Mesozoic conglomerates conform to this definition, and, as shown in the following table, resemble very closely in mineral composition the rocks obtained by Goldschmidt himself.

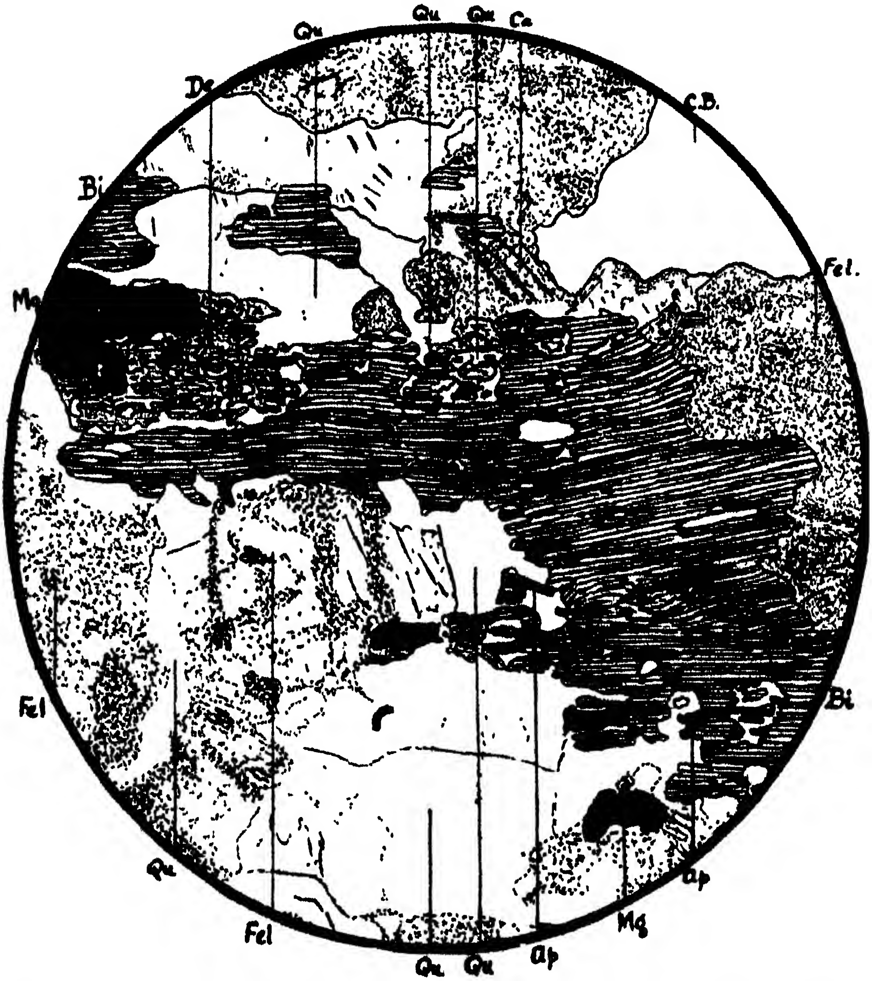
	No. 5	No. 1	No. 45	Trondhjemite Dragaasen	Trondhjemite Frenstad	Trondhjemite Skavlien
Quartz	24	25	30	23	21	31
Muscovite	1.5	—	—	—	2	4
Potash Felspar	(8)	(7)	7	(4)	(9)	7
Albite	57	50	47	49	56	46
Anorthite	6	13	13	15	8	8
Biotite	2	5	3	8	5	5
Augite	—	—	—	1	—	—
Ore and Apatite	0.4	1	1	0.2	0.1	0.4

The mineral content of No. 5 in the table above was measured accurately with a Shand's recording micrometer, but those of Nos. 1 and 45 are estimations by eye only. The three right-hand columns show Goldschmidt's figures (1922, p. 10).

As far as the writer is aware, quartz-biotite and quartz-biotite-felspar intergrowths similar to those found in sections No. 2094 and No. 2095 (Text Fig. I) have rarely been described. In the absence of any evidence of metamorphism

* Compare sodic igneous rocks described by Bartrum from Jurassic conglomerates in the Kawhia district, New Zealand.

it would appear that the intergrowth is probably the result of partial replacement of the biotite during late stages of crystallisation of the rock under the action of its own highly siliceous residual liquid.



Text Fig. I.—Quartz-Biotite Intergrowth (No. 2095). Q.: quartz; Fel.: felspar; Bi.: biotite; Mg.: magnetite; Ap.: apatite; Ca.: calcite; De.: decomposing biotite.

Rocks similar to the trondhjemites and the quartz-mica-diorites have lately been described by Bartrum and Benson (1932) from the Fiord region near Preservation Inlet in the south-west of the South Island of New Zealand.

The fact that pebbles of albite-dolerite, ceratophyre, and trondhjemite occur together in the conglomerates suggests, from their common richness in sodic felspar, that they may be consanguineous.

With reference to the albite-dolerites, the writer has been able to compare them with very similar rocks described

by Dr. Benson (1915) from the Devonian System of New South Wales.

(c) Basic rocks (basalt glass) are also present to a minor extent.

(d) A great number of the plutonic rocks show strain structures, while some of them have been partially crushed.

(e) Two gneisses (Nos. 2127 and 2128) occur as pebbles in the Clinton Triassic conglomerate. The problem of their origin is a difficult one, and nothing definite can be stated here except, perhaps, that the abundance of biotite in them suggests a sedimentary or composite rather than an igneous nature for the original rock.

(f) The crystals of biotite in some of the rocks show large, dark, pleochroic haloes surrounding small zircons. In recent years it has been established (Holmes, 1927, p. 67) that the largest haloes produced by elements of the uranium family should have a radius of 0 016 mm., and those produced by elements of the thorium family a radius of 0 02 mm. The largest halo, however, measured in the rocks at present under description was 0 053 mm., an unusually large dimension. Similar large haloes have recently been described by Iyer (1932, p. 500) from Indian granites (0.030 mm. radius), and by Wiman (1930)* from Swedish granites and gneisses (0·057 mm. radius).

(g) Pebbles of greywacke, mudstone, carbonaceous shale, and slate are present, but there is nothing resembling the schists of Central Otago.

(h) In conclusion, it may be stated that the terrain from which the Mesozoic conglomerates, sandstones, mudstones, etc., were derived, consisted in part of greywacke, mudstone, shale, etc., and partly of igneous rocks including plutonic, hypabyssal, and effusive types, the former perhaps predominating. In what direction this terrain lay from the present area is a matter of uncertainty, although the evidence afforded by the presence of pebbles similar to the granites and diorites of the Fiordland district indicates that it may have been somewhere to the south-west.

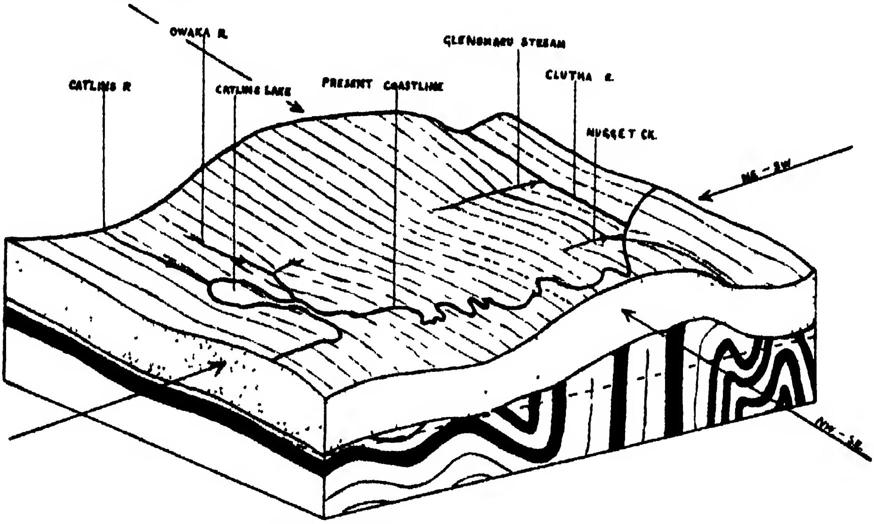
GEOMORPHOGENY.

GENERAL.

The orogenic movement which followed upon the deposition of the long series of Triassic and Jurassic sediments reached its maximum in the early Cretaceous. Northwards of the area the Mesozoic strata were flung into broken or overturned folds, while further south, where the movement and stress were not so intense, a number of shallow anticlines and synclines were produced. Succeeding this orogeny

* Abstract in *Am. Jour. Sci.*, Volume XXIV, Sept., 1932, p. 248.

there was probably a period of erosion and perhaps peneplanation. Submergence then took place, and Late Cretaceous (?) and Tertiary (i.e., Notocene) sediments were laid down. Emergence followed, and warping of the new land surface took place in the following manner. (See Text. Fig. II.)



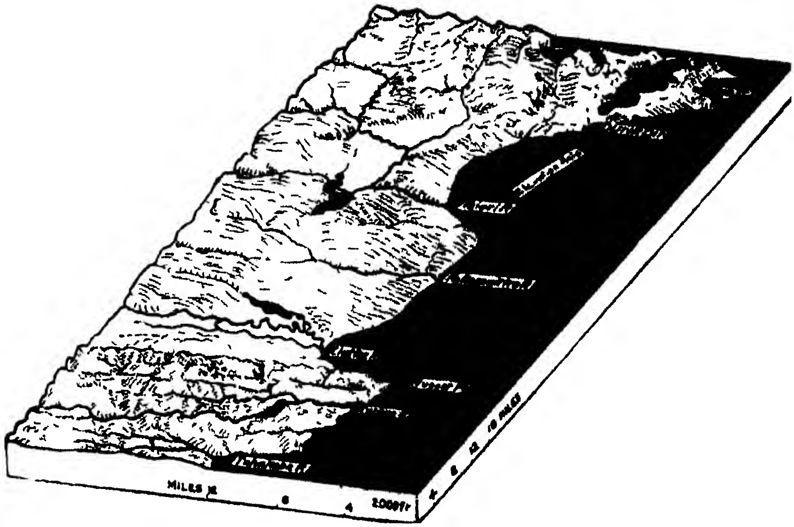
TEXT FIG. II.—Block Diagram showing positions of consequent streams upon warped surface of Notocene sediments (dotted). The arrows show the directions of the warp axes (N.W.-S.E. and N.E.-S.W.).

The land surface was first warped on north-west south-east axes pitching gently to the south-east, and as a result of this the courses of the Owaka and Catlins Rivers were determined by a broad pitching syncline. The whole region was then affected by a north-east south-west crosswarping movement which continued to operate for a long period. Hence, by this latter movement, the position of the Glenomaru Creek as a tributary of the Clutha River was doubly determined. The Glenomaru Creek, then, drained the northern flank of the broad anticline, and was localised thereon at an *early* stage by the *synclinal* axis of the crosswarp. By the crosswarp also was probably formed the shallow basin-like depression now containing the Catlins Lake and the alluvial flat around Owaka township. The effect of continued or renewed crosswarping movement at a late date is indicated by the formation of the swamp near Owaka (perhaps formerly a lake) and its outlet gorge. A certain amount of regional depression probably took place due to the formation of the Catlins Lake.

In time the whole of the overlying Notocene sediments were eroded away, and the previously determined courses of the Glenomaru and Nugget Creeks were superposed upon the underlying Mesozoic rocks in such a way that they flowed in a direction mainly transverse to the strike. Subsequent tributaries were then eroded in the softer of the Mesozoic strata, and the topography gradually assumed its present form.

The above hypothesis as to why the Glenomaru and Nugget Creeks should pursue courses independent of the general strike of the region

was adapted from the explanation by Douglas Johnson of Appalachian Geomorphic Evolution (1931). The application of the theory is not to be confined only to the area under discussion, for by a glance at Text Fig. III it can be seen that the general direction of drainage of adjoining areas is north-west south-easterly, while the north-east south-west crosswarping has been active in the formation of inland plains and lakes, and the cutting of gorges by the Taieri and Tokomairiro Rivers.



TEXT FIG. III.—Block Diagram (by Dr W. N. Benson) to show the position of the N.E.-S.W. elevation axis along which the crust has been warped upward, causing ponding of the rivers and the formation of gorges where the ponded rivers have cut their way out to the coast. Note the decided difference in topography between the schist (north of Clutha River) and greywacke (south of Clutha River) areas.

The surface forms of the greater part of the area are quite characteristic of a region where a steeply dipping series of alternately hard and soft beds is encountered. The softer layers, consisting of claystone and mudstone, weather more rapidly than the interstratified greywackes and sandstones, due to their finer grain-size and abundance of minute joints The result is a series of long parallel sandstone and greywacke ridges which are separated by deep valleys excavated in the mudstone and claystone. Where exceptionally wide bands of the less resistant rock occur (e.g., extending back from Sandy and Cannibal Bays, and to the south-east and north-west of Owaka), the topography is notably subdued. (See Plate 51.)

The main creeks (Glenomaru Stream and Nugget Creek), as explained, are superposed consequent streams. In general, they flow across the direction of strike, and their tributaries, which have cut back along the softer bands in the direction of strike, are of the subsequent type. The long sandstone ridges, then, for the most part,

may be termed "subsequent divides." The subsequent tributaries, in their turn, have smaller insequent tributaries which drain the slopes of the subsequent divides. The resultant stream-network thus has a typical trellised pattern (Marshall, 1912, p. 40; Cotton, 1922, p. 83). The texture of dissection is fine, and the cycle of erosion has now reached the mature stage. A certain amount of rejuvenation has followed upon a recent uplift of about 20 feet, causing many of the smaller creeks to cut little gorges in their older valleys.

COASTAL FEATURES.

From Campbell's Point to Nugget Point the coastline consists of open sandy stretches separated by small headlands which continue seawards for some distance as reefs exposed at low tide. From Nugget Point to Cannibal Bay the coast becomes precipitous and inaccessible except where it is broken by a few of the larger bays. Some of the cliffs between these two points plunge sheer into the sea from over 300ft. and are very dangerous at their bases on account of the slippery nature of the boulders and the rapid tidal rise. Between Cannibal Bay and the Catlins River mouth the sandy shore-line is broken only by the perpendicular cliffed embayments of False Islet.

The most recent land movement, viz., an uplift of from 10 to 20 feet, is clearly demonstrated by raised beach remnants and wave-cut platforms at various points, particularly between Roaring Bay and Campbell's Point. The small, boggy, coastal plain lying behind False Islet is the result of this uplift also, for it is backed by ancient cliff remnants at several points where it joins the eastern margin of Jacob's Hill.

The sandspit joining False Islet to the mainland is a tombolo, and was probably formed shortly after the uplift.

ACKNOWLEDGMENT.

The writer is indebted to Dr. W. N. Benson and Dr. F. J. Turner, Otago University, for helpful criticism and assistance rendered during the compilation of this paper. To Mrs A. Campbell, of the Nuggets, thanks are also due for the loan of a small cottage in that locality.

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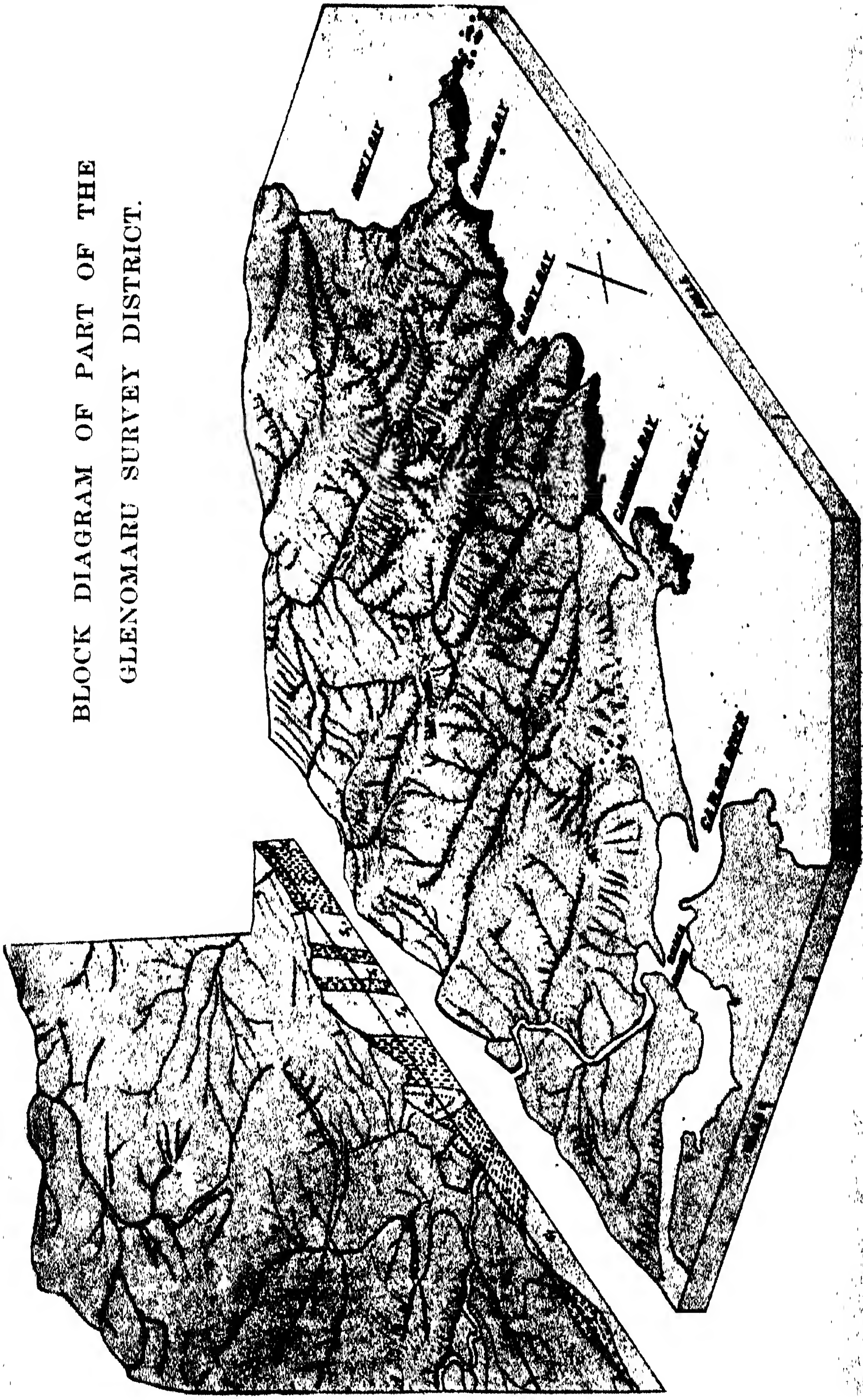
BLOCK DIAGRAM OF PART OF THE GLENOMARU SURVEY DISTRICT.



Follow pl. 51

Further Notes on the Geology of the Trelissick or Castle Hill Basin.

No. II.

With Sketch Maps and Plates.

By R. SPEIGHT, M.Sc., F.G.S.,
Curator of the Canterbury Museum.

[*Read before the Canterbury Philosophical Institute, 6th December, 1933; received by the Editor, 13th April, 1934; issued separately, March, 1935.*]

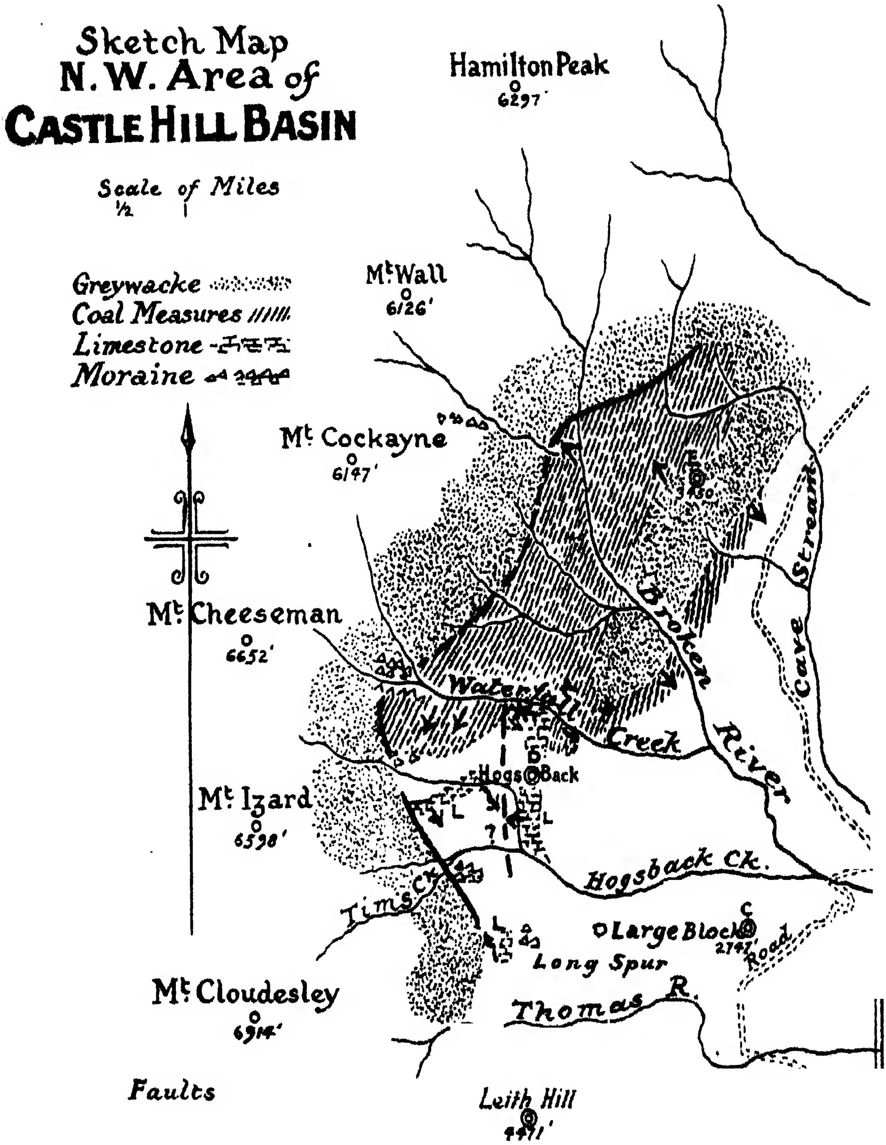
TABLE OF CONTENTS.

A.—STRATIGRAPHY OF THE NORTH-WEST AREA OF THE BASIN.

See Map A.

DURING recent visits to the Castle Hill district all available time has been devoted to an examination of the western side of the basin and particularly of the relation between the Notocene beds and the underlying pre-Tertiary greywackes and argillites. Since my previous accounts (1917 and 1919) a considerable area of bush has, unfortunately, been destroyed by fire, but this has enabled a clearer view of the structural features of portions of the margin of the basin to be obtained. The chief alteration in the account of the locality, as given formerly, is the record of the presence of an area covered with Notocene beds in the north-west corner of the basin, for north-west of the disjointed greywacke ridge which extends north-east from Waterfall Creek across the upper part of Broken River to near the road crossing of Cave Stream (formerly Murderers Creek) there lies an extension of the lowest beds of the series, i.e., coal measures, sands, clays, etc., not marked on the map (1917). This greywacke ridge forms part of the irregular floor of the basin and is the core of an anticline whose upfolding was posterior to the deposition of the covering beds, and is now exposed by the stripping away of what was once a continuous cover from the axial portion of the anticline. In the area just referred to from near Cave Stream almost to Waterfall Creek there is no remnant of limestones or other calcareous beds which characterise the middle portion of the Notocene series in the Trelissick area, only the lower members persisting, which are of Senonian age (Speight, 1917, p. 344). At the south-western end of the ridge near Waterfall Creek the middle Tertiary limestones occur, and their arrangement here and on the Hogsback clearly indicates that they experienced the same movements as the beds further north-east flanking the greywacke ridge.

The most typical section is that disclosed by an examination of Broken River above the first greywacke gorge, from three to four miles above the road crossing. Lying unconformably on the northwest side of this greywacke ridge are coal measures, consisting of sands, grey, greenish-grey with yellow efflorescence, and white, with



Map A.

streaks of shale, and one bed of poor lignite showing. They strike N. 15° E. and dip west at low angles. Their contact with the greywackes towards the west is a reversed fault, hading 80° in a direction N. 15° W. This is the only clear contact to be seen in any part of the area.

The beds extend N.E. over a low saddle lying N.W. of Trig. E into the neighbouring valley of Cave Stream, where their western margin is almost certainly a reversed fault, and from there on to the slopes of Mount Manson, judging from certain topographic features. South-west from Broken River the country is almost completely masked by terrace gravels and bush, but the coal measures are occasionally exposed in the banks of deeply incised streams. The beds flanking the greywacke axis are replaced in this direction by a definite anticline, and to the west lies a flanking syncline, the overlying limestones being involved as well as the coal measures, and show on the surface.

On the extreme western end of the ridge south of Waterfall Creek there are occasional exposures of coal measures including ferruginous concretionary sandstone, striking N.W.-S.E., and lying at right angles to the beds nearer the Hogsback, the junction between the two sets of beds being evidently a fault, with only a small throw, since coal measures lie in contact with coal measures on either side of it. The dip of the beds west of the fault is at low angles to the south-west. West of the upper part of the Hogsback Creek is a mass of limestone forming another hogsback, a quarter of a mile in length, which, owing to the destruction of bush, is more clearly seen than when I wrote my last paper (1919, p. 157). The strike is E.N.E with a southerly dip at angles of 50° and over, so that it is almost parallel with the coal measures on the ridge to the north, and, judging from the stratigraphical relations elsewhere in the basin, they are both part of the same sequence. At the western end of the limestone ridge it abuts against the greywacke, and is tipped up at the junction, so that it presents a fault contact similar to that in Broken River.

The limestone in the bed of Hogsback Creek, at the end of this ridge, has evidently suffered some dislocation, and the strike varies between N. 55° E. and N. 75° E. where it crosses the stream. The dip is nearly vertical and varies in direction also. The bed probably continues to the north-east along the face of the hill and junctions with the limestone showing in the western limb of the syncline just south of Waterfall Creek.

In a stream rising between Mounts Cloudesley and Izard, known as Tim's Creek, which joins the Hogsback Creek near the southern end of the limestone ridge, occurrences of coal appear in several places. Their dip and strike are obscure, but near the junction with the Hogsback Creek they seem to conform with that of the limestone of the Hogsback itself. These beds are probably the stratigraphical equivalent of the upper coal measures as they appear in the Thomas and Broken Rivers; that is, they are posterior to the limestone. This is certainly the case in the lower part of the creek, but owing to the limited exposures and the absence of fossils this cannot be told for certain as regards the higher part.

The next appearance of the Notocene beds along the western margin of the basin is on the northern flank of Long Spur near its proximal end, where limestone shows through the covering of soil and debris for a few chains. In the part of the exposure furthest

downhill the beds are much corrugated and have a general vertical dip and a strike N. 10° E., that is, in a line with the main mass of the Hogsback limestone. The ridge formed by the limestone is sinuous, but has a general strike of N. 20° E. and a westerly dip of 50°, sometimes 60°. The orientation of the upper part of the exposure near the crest of the ridge is in the direction of the outer flank of Leith Hill, which lies south of the Thomas. In one place there is a break across the bed which suggests a lateral movement of adjacent blocks following on a differential horizontal thrust.

This limestone mass probably forms the western wing of a syncline whose axis is sub-parallel to the upper part of Tim's Creek, the limestone west of the upper part of the Hogsback Creek forming the other wing, and, if so, the synclinal axis meets the line of the Hogsback ridge at an angle. This syncline is cut off on the west by a fault running along the base of the Craigieburn Range, and perhaps on the east by another running parallel with the Hogsback and west of the line of the creek as it follows along the base of the ridge. This may be a continuation of the undoubted fault which crosses the ridge south of Waterfall Creek. There is a possibility, however, that this last fault is of minor importance, and may be only a phase of the wide syncline of Tim's Creek, which pinches together when traced north and becomes the narrow syncline above the fall in Waterfall Creek When this fold is traced south along the Hogsback, the eastern wing becomes increasingly tilted to the west and becomes slightly overturned at the southern end of the Hogsback ridge, and is no doubt faulted as well. This folding demands first of all a thrust from the N.N.W. or S.S.E. to account for the syncline whose axis runs along Tim's Creek, and as well a thrust from the W.N.W. or E.S.E. to account for the folding along the line of the Hogsback. The position may be explained by the syncline having an axis pitching S.W., with the south-easterly wing pushed over by a thrust from the E.S.E.

There seems to be a break between the end of the Hogsback and the limestone on Long Spur, and there must be a break east of this to account for the position of the "Pareora" beds in the lower part of the Hogsback Creek, south-east of the Hogsback ridge, and also those on the distal end of the Long Spur.

The whole locality is thus one where the beds are markedly disturbed, the frequent brecciation of the rock, and the rapidly varying dip at high angles, emphasising the point. The true relationship in some cases is therefore difficult to determine.

Further south along the slopes of Leith Hill the contact of the limestone beds with the greywackes appears to be a reversed fault, and this remark applies to the isolated mass of limestone at the mouth of the Whitewater gorge, which is cut off from its related beds to the east by a normal fault. In the Coleridge Creek section (1917, p. 334) the arrangement should be amended in the direction of representing beds beneath the limestone on the western side of the creek. As the result of a slip, the coal measures beneath the limestone are exposed.

It thus appears that the western boundary of the basin as a whole is marked in places by a reversed fault with steep hade, and it may reasonably be inferred that the contact where obscured is of the same nature. There is no evidence of marked overthrusting to indicate a considerable push from the north-west. In parts of the floor of the basin the fold directions are varied; for example, the line of the Thomas River shows a fold oriented almost E.–W., and this is practically the direction of the folding between Tim's Creek and Waterfall Creek; also the dip of beds to the east of Cave Stream, forming the mass of Flock Hill, swings round through a right angle. I can see no reason, therefore, for modifying my opinion that the folding can well be explained as the result of adjustments when the basin was formed as the result of the faulting down of a portion of the pre-Tertiary peneplain and its covering beds.

B.—Effect of Removal of Bush.

There are also one or two matters of purely physiographical interest that I should like to refer to. First of all, there is the effect of the removal of the bush covering from parts of the western side of the basin. When I examined this area originally, some forty years ago, the upper courses of streams such as the Thomas and Hogsback ran in confined channels obstructed by large boulders. Now these channels are filled up and the streams wander over somewhat wide shingle-covered beds owing to the increase in the supply of waste. Standing trees over a foot in diameter are partially buried and killed by the encroachment. Were this to continue for a substantial period it seems possible that the stream beds would be filled with waste to a degree comparable with what existed before the terraces were formed, and this supports the contention concerning the important effect of excessive waste on the history of terrace formation in this part of the country.

The deposition of detritus suggests consideration of what were the conditions of the floor of the basin during Pleistocene times and subsequently.

C.—Glaciation.

Both Hutton (1887, p. 395) and McKay (1881, p. 5) maintained that the basin had not experienced the direct effect of glaciation, but Haast (1879, p. 392) stated baldly that the Waimakariri and Rakaia Glaciers once joined by way of the pass where Lake Lyndon is now situated. In view of these conflicting opinions, the matter was reconsidered in order to arrive at a definite opinion if possible.

Near the source of Broken River the valleys are certainly headed by corries, and small valley glaciers came out on the floor of the basin in that locality. At the head of the main stream lies a U-shaped glacial trough and above it a corrie at the level of 5000 feet (Plate 52). Similar features occur in the valleys to the west of this.

On the south side of Tim's Creek, at a point where it leaves the greywacke slopes and enters the floor of the basin, there is an area covered with morainic dumps (Plate 53). As far as can be seen, these are composed of large angular blocks which can neither be slip nor a stream deposit. At the outlets of Hogsback and Waterfall Creeks from the greywacke range there are similar deposits with the form of ridges of large blocks converging downstream; that is, they are latero-terminal moraine, and in the latter creek there is true terminal moraine. These deposits do not belong to a recent phase of glaciation, judging from their surface features; they are rounded and covered with soil, and compare most closely with the outermost morainic deposits of the Rakaia Valley, and therefore belong in all probability to the stage of maximum glaciation, which dates from a time long antecedent to the moraines which have been little modified.

The northern side of Long Spur and the terrace at its base are marked in various places by nests of large angular blocks, but the most remarkable block lies on the terrace about three chains from the base of the spur. It is angular and partly embedded, but the visible portion measures 15ft. by 14ft. by 5ft. (Plate 54), composed of a type of greywacke not showing on the mountain slopes in its immediate vicinity, and it lies over half a mile from the base of the hills. Transport by glacier appears to be the only way in which it can have been carried and deposited in its present position.

These are the only definite evidence of the presence of ice in the basin, but there are other suggestive phenomena. First of all, judging from the forms of the hills near Craigieburn, a powerful stream of ice must have run past the north-western end of Broken Hill towards Broken River and Mount Torlesse. Faceted spurs and ice-shorn slopes indicate this clearly. There are also similar faceted spurs on the slopes of the Craigieburn Range just inside the basin. These may be attributed to faulting, though there is no clear evidence from the floor of the basin itself of recent faulting on this line. The main faulting must have been pre-glacial.

At the other end of the basin similar faceted spurs occur on the face of Mount Torlesse, and on both sides of the valley leading to Lake Lyndon, and probably in the upper valley of the Porter River in the direction of Coleridge Pass. These latter, as well as those near Lake Lyndon, may be fault-scarps, but the latter are more strongly suggestive of glaciation, since, if fault scarps, they would demand evidence of faulting on the same line in the vicinity of Porter River, and this does not occur. It must be remembered, too, in this connection that ice did actually cross the spurs of the Benmore Range to the south-east of Lake Lyndon at a height of over 3000 feet. Although this may more reasonably be attributed to a distributary stream from the Rakaia Valley, the deposit may have been caused by a glacier coming down from the north past Lake Lyndon, and

to this glacier may be attributed the faceted spurs on the walls of the valley north of the lake, and perhaps also the moraine across the Acheron Valley below the lake. There is also the practical certainty that ice invaded the basin from the Rakaia Valley by way of the Coleridge Pass, since there is evidence of the presence of ice on the Rakaia side of the pass in its immediate vicinity at a much higher level.

Thus we have definite evidence that glaciers came down on to the floor of the basin from the Craigieburn Range on the west, while at the northern and southern ends there are phenomena which can be best explained by the presence of ice. If this is so, then it is likely that a considerable part of it, or perhaps even the whole of it, was covered by ice at the height of the glaciation. What, then, is the reason for the absence of traces from its floor? One can only suggest that the streams issuing from the retreating ice-front removed all traces of glacial deposit from the eastern and north-eastern portions. This is quite conceivable when one remembers the long reaches of the river valleys of Canterbury which show no deposits to be credited to ice action.

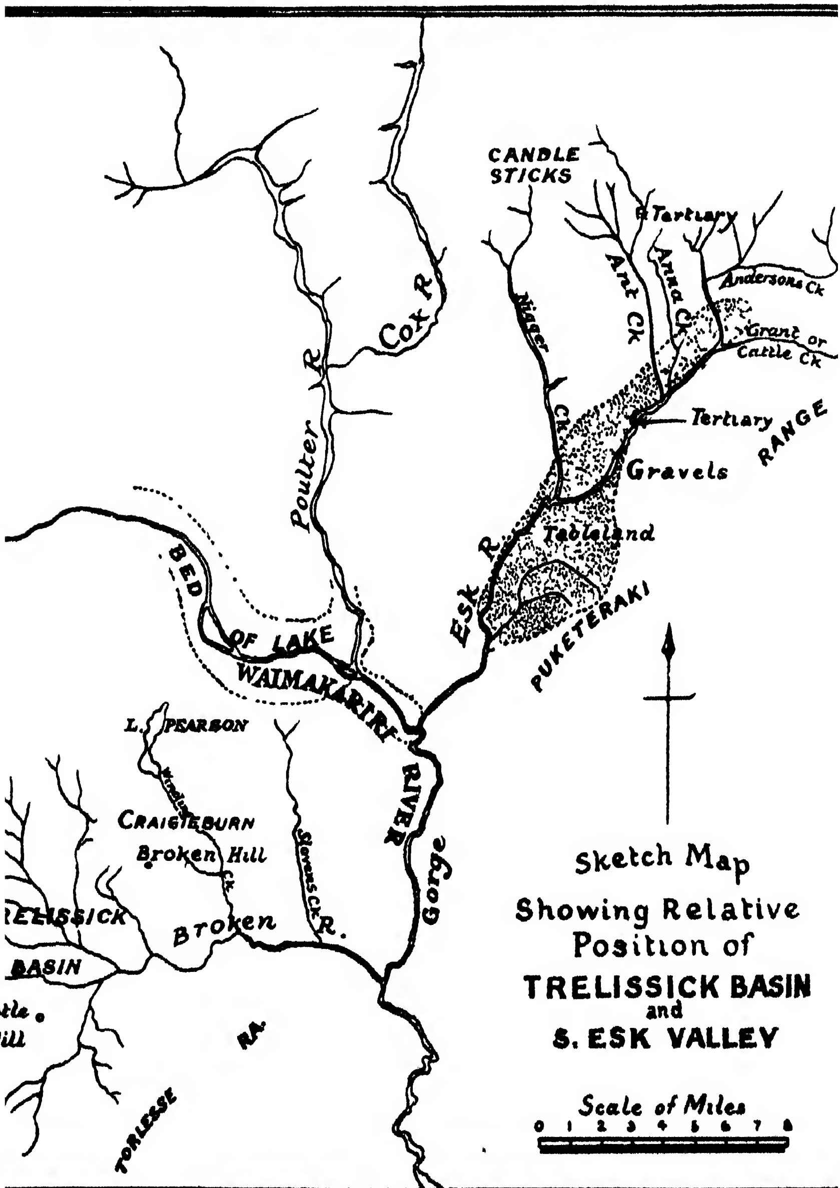
The general evidence indicates that a considerable amount of erosion of the Tertiary beds had taken place before the onset of the glaciation, and it no doubt continued when the ice was retreating from the basin and its vicinity, and after it had left the area. Some of the land forms on the floor of the basin date from pre-glacial times. It may be concluded that the Long Spur and also the terrace north of it had something of its present form during the ice advance, for the moraine at the mouth of Tim's Creek, as well as the large erratic lying on the top of the terrace some distance away, have been laid down on this terrace, so it was in existence in pre-glacial times The large blocks on the flanks of the spur may likewise have belonged to a lateral moraine of this glacier, and have been shed from its side when the glacier covered the floor of the terrace.

D.—WAS THE BASIN ONCE A LAKE?

See Map B.

McKay (1881, pp. 58–60) considered that the basin was at one time occupied by a lake, that debris from the neighbouring mountains poured into it, ultimately filling the lake and aggrading its floor, while an outlet was being lowered through the downward cutting of the stream to the east and north-east of the basin, the limestones being incised as the Broken River and Waimakariri further east lowered their beds. During this period of delayed erosion aggradation continued, and the channels of the streams were widened in the weaker beds above the limestones.

Although this sequence of events may be reasonable, I know of no direct evidence of the former presence of a lake in the Trelissick Basin. There are no stratified gravels or silts that I am aware of, and the floor is not level This may not be an insuperable objection to the hypothesis, as the terraces and the floor itself may have been



Map B.

warped as the result of earth movements, or the basin may have been tilted as suggested by Hutton, although he puts his tilting much earlier. I can see no difficulty, however, in the basin having been a waste-filled plain, like the Hanmer, Maruia, or Upper Buller Plains, or the Mackenzie Country, while glaciers filled the neighbouring

valleys. No doubt each of the streams issuing from the mountain tract to the west of the basin had its fan, and the coalescence of these formed the floor of the area, and thus its approximately—for it is only approximate—level surface can be explained, the departure from absolute horizontality being due to the varying conditions of the streams issuing from the Craigieburn Range or from the front of the ice to the north or perhaps to the south. These streams would differ in size and in the amount of waste material they carried, and thus their grade would vary, causing any unevenness in the main floor existing now.

The hypothesis of the former existence of a lake must be considered in the light of the fact that a lake did occupy the floor of the Waimakariri Valley in the reach downstream from the Cass to the mouth of the Esk. (See Map B.) Its former presence is evidenced by glacial silts and by level terraces marking its old shore line. Glacial silts, some of them varved, occur in the lower reaches of the Poulter, but I have seen none in the Esk. The traces of this lake indicate that it was at a higher level than the present floor of Slovens Creek, but this would not account for the existence of a lake in the Castle Hill basin. This lake, too, was ponded back behind a rock barrier just below the mouth of the Esk, now deeply incised by the main stream of the Waimakariri. The hollow above the barrier may have been structural in origin, but it was certainly modified by glacier action. If due to movements of the crust they must either have been pre-glacial or contemporaneous with the occupation of the upper part of the valley by the glacier, since glacial silts occur in it. It is not maintained that the present hollow was in existence then, but a hollow did exist for certain. The movement responsible for the formation of the barrier must have commenced, if, indeed, it had not concluded, before the end of the glacier advance.

There is, however, in the Esk Valley a great deposit of stratified gravels, best developed on what is called the Tableland, a flat area 3000 feet above sea-level, and lying three to four miles above the confluence of the Waimakariri and Esk (Plate 55 and map B). This was once covered with forest, but a fire has destroyed most of it, though a bush-covered extension of the plateau continues for two miles further up the Esk in the form of a high terrace. The beds of which the Tableland is composed lie flat, that is, parallel to its upper surface; they are mostly of gravel, but this is interstratified with beds of sandy clay and sand. They rest on greywacke, and the river has now cut its course through the gravels and incised the solid basement. It might be noted here that the destruction of bush was followed by marked erosion of the gravels on the edge of the plateau facing the Esk, and "badland" topography has become typically developed. (See Cotton's Geo-morphology of New Zealand, p. 191.)

These gravels occur on both sides of the stream, and extend north-east beyond the Tableland at a lower level across the lower courses of the Nigger and Ant Streams, past Anna Creek and Grant (Cattle) Creek nearly as far as Anderson's Creek. They reach north-

west nearly a mile up the Ant and Anna, in the neighbourhood of which they form an extensive flat terrace lying at a height of from 2700 to 2800 feet. The drop to this terrace from the top of the Tableland is sudden, and there are no intermediate shelves. This is incised in turn, and there are numerous terrace remnants at various levels till the bed of the Esk is reached. The suddenness of the drop from the Tableland and the extent of the terrace just referred to are remarkable (Plate 55).

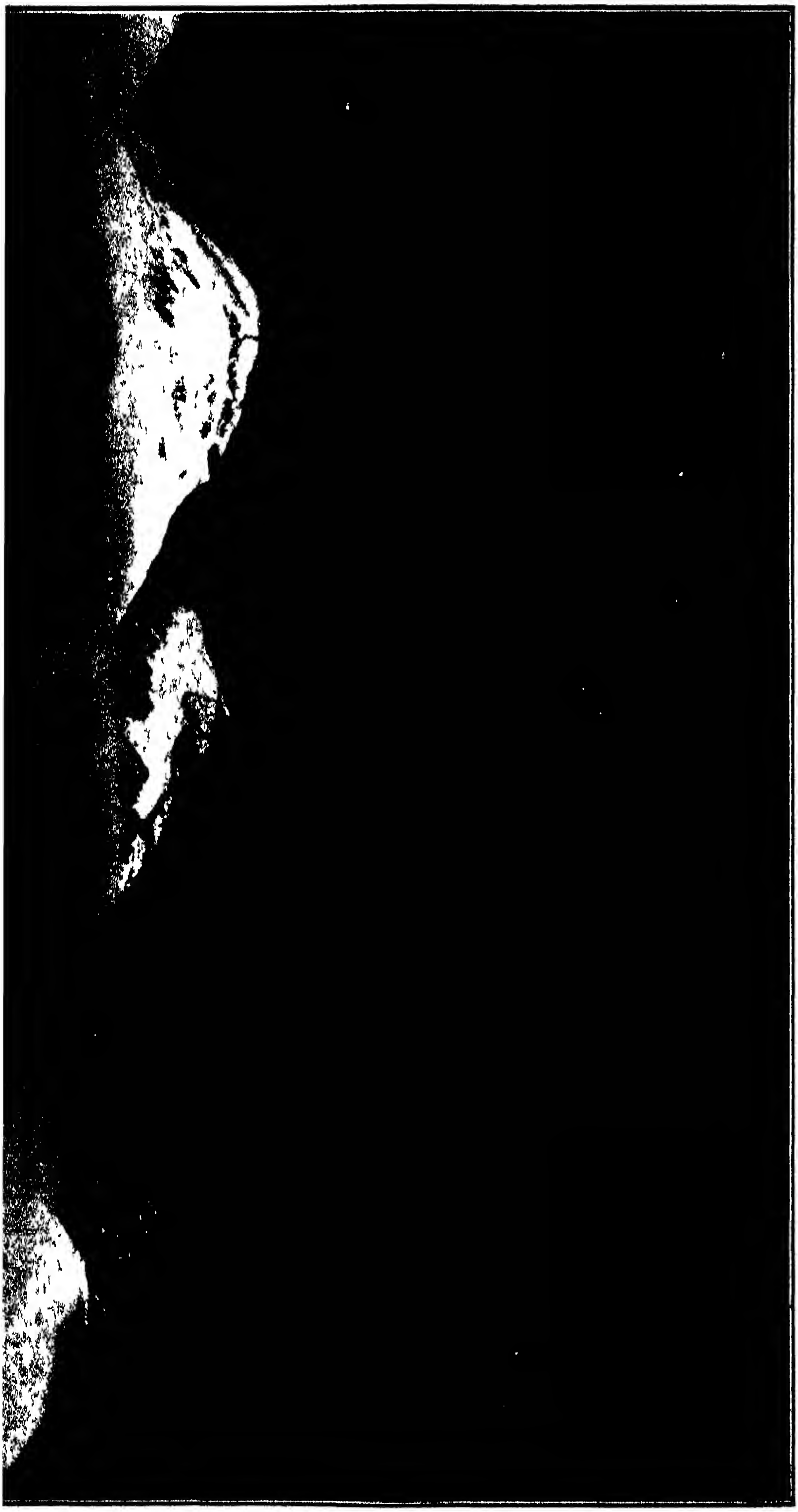
The gravel deposit is most extensive, and therefore indicates some special conditions favouring its accumulation. In general the bedding is flat, but along the northern boundary of the terrace the beds had been tilted prior to its formation. The strike is here W.N.W.–E.S.E. approx., and the dip southerly at angles of from 25° to 30°. The lowest beds exposed in the Ant consist of whitish and greenish-grey sands, sandy clays, and irregular gravels interstratified with sands. In the Anna, which lies parallel with the Ant and a short distance to the east, green-grey sands and chocolate coloured clays occur interstratified with subangular gravels, the largest pebbles of which reach 8 inches in diameter. These beds extend north-east to the main Esk between Cattle and Anderson's Creek on the slopes of the Puketeraki Range, and have the same strike and dip throughout. The inclination is due to subsequent deformation and not to fore-setting. There are also heavy deposits of gravel in the valley of the Poulter, above and below the junction of the Cox.

There is no precise evidence as to the age of the Esk gravels, but they may be tentatively assigned on lithological grounds to the Kowai Series of North Canterbury. Marine Tertiary beds do occur in the locality, but the relations of the gravels to them is obscure. Large fragments of rock containing fossils were found during a recent trip in a tributary of the Ant on the slopes of the Candlesticks at a height of approx. 3500 feet, and Dr Marwick has assigned these to the Mid-Tertiary, and almost certainly to the Awamoan. On the right bank of the Esk, about a mile below the Anna Hut, there is an exposure consisting of the following sequence:—

1. *Grey sands,* lying down at water level.
2. *Coal,* lignitic, 6 inches thick.
3. *Fireclay,* 6 to 12 inches.
4. *Streaky sandy shales and grey sands,* 15 feet.
5. *Yellowish-white sands,* with stains of iron oxide, the pebbles in the vicinity being covered with a white incrustation of iron sulphate or alum.

These beds strike N.E.–S.W. and dip N.W. at high angles. They are affected by a fault which runs in the same direction. The exposure is obscure owing to the height of the river and the cover of terrace gravels, but at the downstream side of the occurrence, which, after all, is only about 4 chains in length, there are irregular cemented gravels resting on greywacke in close proximity, but their

Glaciated Valley at the head of Broken River, with cirques at the head and cross-sections modified by screes coming in from the sides and from the rock-slopes above.



Morainic Dumps at mouth of Tim's Creek, showing in the middle Cirques at head of Waterfall Creek on the slopes of Mounts Cockayne and Cheeseman in the background

Perched Block, 15ft by 14ft by 5ft, on the terrace north of Long Spur, which shows on the left. The stick leaning against the rock is over 4ft in length. The morainic dumps of Plate B show to the left of the rock in the middle distance. Large blocks also occur along the fringe of bush, and on the slopes of Long Spur near the beech tree. Some of these are 10ft in length

precise relationship is obscure as well. I am told by Mr R. Turnbull, the lessee of the Mount White Station, that fossils have been found in close proximity to these beds, though I saw none on my various visits. Unless they are disturbed locally owing to faulting, their pronounced dip and the difference in strike from that of the gravels in the vicinity, though it must be admitted not the immediate vicinity, indicate that they underlie the gravels unconformably

The flatness and even stratification of the gravels indicate that they were laid down in comparatively still water, and it is thus possible that a lake occupied the lower part of the course of the Esk. There is at present no rock barrier indicated that would pond back this water from the Waimakariri side to the height of the top of the Tableland, but there is a certainty that the ice at its maximum extension could furnish such a barrier, for there are clear evidences of ice at a height exceeding 3500 feet in the Craigieburn region of the Waimakariri basin, and this would be quite sufficient to furnish the required barrier if the ice extended on to the slopes of the Puketeraki Range below the junction of the Esk. There is little doubt that this was the case, and if the lower reach of the Esk were free from ice at the same time, there would be opportunity for the deposition of these gravels under the required conditions. A difficulty in accepting this explanation in its entirety is the determination of the precise date of these gravels. In order for it to be satisfactory, they must date from the time when the central Waimakariri was occupied by ice and the lower reach of the Esk free from it and occupied by water. The synchronism cannot be demonstrated. There is therefore no definite support from the valley of the Esk of the contention that the Trelissick Basin was once a lake, but the evidence is in support of the hypothesis that the barrier of greywacke to the east of the basin was in existence in pre-glacial times or at any rate before the ice had commenced its last retreat, and that it has been cut through subsequently.

It is noteworthy that the main coalesced drainage from the Waimakariri intermont follows along the base of two ranges, viz., the Puketeraki Range and the Mount Torlesse Range, and there is comparatively little drainage in the middle of the area, only two streams being worth mentioning, viz., Winding Creek and Slovens Creek, both of minor importance. This may reasonably be explained by supposing the main part of the basin to have been filled with ice, and the streams therefrom discharging along the margin of the main flow, just as the Murchison River discharges along the margin of the Tasman Glacier. The impinging of the ice against the slopes of Mount Torlesse would provide a temporary barrier against the cutting down of the river channels in the Trelissick area, and thus help in the formation of terraces. All the same, the dominating agencies in this area connected with the formation of terraces appear to be the retardation in the cutting down of weak beds by solid rock barriers, such as the limestone and greywacke to the east of the Trelissick Basin, and the latter downstream from the mouth of the Esk, as well as the warping of the crust on an axis

running N.E.–S.W. and practically cutting across the Waimakariri in the gorge of that river.

I am making no further reference to the terrace system of the basin, since I understand that Mr Jobberns has the matter in hand.

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Notes on the Franz Josef Glacier, February, 1934

By R. SPEIGHT, M.Sc., F.G.S.,
Curator of the Canterbury Museum.

With Maps and Photographs.

[Read before the Philosophical Institute of Canterbury, 4th April, 1934, received by Editor, 13th April, 1934; issued separately, March, 1935.]

IN 1910 Dr. J. M. Bell gave in his Geographical Report on the Franz Josef Glacier an accurate record of the position of the terminal face as it appeared in the years 1908 and 1909. Also Mr R. P. Greville, a surveyor on Dr. Bell's staff, selected certain points near the terminal face of the glacier as it stood in 1909, and drove strong iron pegs into the rock to mark its position. All records made subsequent to their placement naturally use these as convenient points for reference.

The present author has visited the glacier on various occasions, and made observations on the face, the results being published in the *Transactions of the N.Z. Institute* in 1914 and 1921, the former based on observations taken by Mr Alec Graham.

In 1893-4 Messrs Douglas and Harper noted the position of the face and left cairns to mark it, and Mr Harper in Volume III of the *N.Z. Alpine Journal* (December, 1926) gives a map showing its position as it stood in 1894, as well as the approximate line in 1926. I should remark, however, that there is a rock near the north-west front fully visible in 1921 and in 1934 which is not shown on the map, although it should have been clearly visible in 1926. By the kindness of the Chief Surveyor for Westland, I have by me a tracing of Douglas's map made in 1898, with a record of the line as it appeared in 1894.

In the following table I have recorded as far as I can the distances of the face from Bell's pegs, as measured in 1909, 1912, 1914, 1921, and 1934, the last measurements being made by myself during a visit in February of this year. Included are also Douglas's obtained from his 1898 map and Harper's own obtained by making measurements on his 1926 map. Records are given in metres, with a plus sign if the ice is in front of the peg, and a minus sign if it has retreated behind it.

POSITIONS OF THE TERMINAL FACE AT VARIOUS TIMES SINCE 1893-4.

From Peg.	Douglas and Harper.	Bell and Greville.	Alec Graham.		Speight.	Harper.	Speight.
	1893-4. (i)	1909. (ii)	1912. (iii)	1914. (iii)	1921.	1926.	1934.
1	−198	−1		−484	−279	−533	−282
2	0	−9		−66			
3	+10	0	15	−37	−160	−110	71
4	+120	−21	23	−58	−100	−39	−53
5	+10	−18	−82	−107	−160*	171	−128
6	−15	−5	80	−98	283*	302	191
7	+90	2	14	−24	−456	−262	−262

* Approximately.

(i) These results are obtained by measurements of Douglas's map of 1898.

(ii) Bell and Greville also located the terminal face in 1908, and a comparison shows that by 1909 it had advanced slightly at nearly every point on the line.

(iii) The figures in these columns were obtained by the kindness of Mr Alec Graham, and were recorded by myself in 1914.

A conspectus of these results indicates that the glacier probably reached a maximum in 1893-4, although at some points it was further forward in 1909, and it must be remembered that a photograph taken in 1867, and examined by Mr Harper, indicated that it was then from 80 to 100 yards further forward still (*Pioneer Work in the Alps of New Zealand*, 1896, p. 306). The records of 1912, 1914, and 1921 show retreat almost all along the line. In 1926 there was a probable advance, and in 1934 the front as a whole was further down the valley than in 1926. The large numbers assigned generally to the distances of Pegs Nos. 1 and 7, which are placed on the bounding walls of the glacier, are due to the outlet of the river being at the side where the large figures are recorded, or due to the river having but recently left that side.

In order to furnish some idea of the present position of the terminal face, the state in front of each peg will be taken in turn, and as the site of these pegs is somewhat difficult to determine at present owing to the growth of scrub, etc., some note will be made of their true location so that subsequent observers may be able to find them readily.

No. 1.—This is close to the end of the formed track to the glacier, but just covered up at present by "riverbed" moraine.

The glacier is back at this point, and abuts against the valley side 280 metres away from the approximate position of this peg. The side of the glacier is for the greater part of the distance about 60 metres from the valley wall. The bearing of the face is first 347°, and then it changes to 26° and continues to the side of Wilson Rock, over which moraine is being pushed so that the plants established on it since 1921 are being destroyed. Only a small part of the solid rock, viz., that at its N.W. corner, is now visible under the mask of moraine and the ice behind it. The ice front at this spot is oriented N.E.–S.W.

It may be appropriate to mention here that the material on the front of the glacier is rounded river gravel, almost entirely of schist, and not true moraine, which is of greywacke with an occasional fragment of slate. The "river-bed" moraine is pushed before the advancing ice and raised at the same time, so that it covers the front of the glacier to a breadth of from 20 to 40 metres, forming a belt parallel to the ice-front. The moraine covering Peg No. 1 is of this material.

No. 2.—This is on the western end of Harper Rock, but from the form of the present terminal face it was of little value for the purpose of measurement. It might be noted that in 1893-4 the ice a little to the west of the peg was slightly further forward than the peg itself.

No. 3.—This is on the top of Harper Rock, near the edge of the southern cliff face, and almost at the corner of the rock. There have been recent heavy falls from the face just below it, and if they continue the peg will soon be displaced.

From the peg, the face of the glacier covered with debris is distant 71 metres on a bearing of 188°. Just west of this point lies Wilson Rock, which was uncovered at my last visit. The ice is pushing river-bed moraine over this, and destroying the plants and shrubs which had become established. At the present time only a few square yards of solid rock show under this cover, and from the general evidence it promises to be completely covered at an early date.

To the east of this the face of the ice is slightly retired, while opposite the end of the unnamed rock to the east of Harper Rock, now known as Teichelmann Rock, there is a pool of water from which a small stream discharges. The ice is now 16 metres from the eastern end of this rock on a S.S.W. bearing.

No. 4.—This is on Park Rock, on the high point immediately overlooking the low ground in the direction of Strauchon Rock. The form of the rock is different from that shown on Bell's map, since to the north it was then partly covered by ice, which crowded over a lower shelf now exposed.

To the south of the peg and distant 53 metres from it, ice occurs covered with debris, most of which is schist and of river-bed origin. This has been pushed forward in front of the ice for nearly 20 metres, and has been shaped into ridges, some of which are overriding the vegetation growing on the rock and on its old covering of debris. At this point the ice is level with the summit of the rock, though distant from it, and it is covered with a thin veneer of true moraine consisting of greywacke and occasional slate.

Apart from the gullies worn on the margins of the glacier, the ice at this point is farther back than at any other point in the face, and it seems to have retreated since Harper made his observations in 1926.

No. 5.—This is near the south end of Strauchon Rock and about 10 metres above the river-bed.

The face of this glacier is about 128 metres from this peg. It is fringed with moraine, and has its front covered with river-bed material. The ice at this point shows an overthrusting of the upper layers, the angles of the thrust planes being usually about 15° from the horizontal, but at times they are greater and again lower. In this part the ice comes forward to just beyond the line between Pegs 4 and 7.

No. 6.—This is about 4 metres above the river-bed on Barron Rock. Between it and the terminal face lies the main stream of the Waiho. In the direction of Peg 7 lies Outlet Rock. This is in a slightly different position from that recorded in Harper's paper. It is said to have been uncovered for 10 yards when seen originally. The rock itself is 20 metres long and 12 wide, with an extension to the south under the river-bed of 20 metres, where another small outcrop shows.

No. 7.—This is on the eastern front of the glacier about 60 metres above the river on a rock generally known as the Gallery Rock, from the gallery which once passed round it and was destroyed in the 1908 advance at this part of the front.

As the main stream issues from a cave on this side of the glacier, the terminal face is distant 262 metres from the peg. Further up the glacier at Roberts Point the ice is crowding over the solid rock, and below this point, at Rope Creek, there is a fringe of bare rock at the side, and even this at present shows signs of being overridden, while lower down still, near the outflow of the river, the ice is right against the rock wall.

A general survey of the whole face shows that it is further forward than it was in 1921, and apart from the eastern margin and Park Rock it is further forward than it was when Harper observed it in 1926. The record of 1921 was obtained when it was near the minimum position. This was noted then as probably being the case, since there was evidence of an advancing wave of ice further up the glacier, as is the case at the present time, for ice is now crowding over Roberts Point on the east and over Cape Defiance on the west side of the glacier.

I have photographs taken in 1927 and 1928, kindly lent by Mr G. E. Mannering, also photographs taken in 1929, kindly lent by Mr J. Mitchell, all of which show that Wilson Rock was hardly as much covered as at present, for the vegetation growing on it shows more in these pictures than it does now. In 1929, however, the ice was much higher behind this rock, and the same holds good for Park Rock. Upstream from the latter the ice was further forward in 1928, whereas the 1929 picture shows a distinct advance north-east of the rock and that the shelf below the peg was then partly covered, whereas it is bare now. This implies a present slight recession at this point. Mr Peter Graham, of the Franz Josef Glacier Hotel, says that an advance set in about four years ago, but that there are always slight oscillations of the face during a general forward movement.

Before leaving consideration of this glacier, one or two features apart from the condition of the face may be referred to. The first concerns the presence of the line of rocks, such as Sentinel Rock, Harper Rock, Park Rock, etc., which form such upstanding objects in the floor of the valley below the ice. They are certainly roches moutonnées, but the face against which the glacier impinged shows very few of the characters which belong to the scour side of such rocks, though they are certainly striated. The upstream faces of Sentinel Rock, Harper Rock, Teichelmann Rock, Park Rock, and the steep rock face where the gallery was once situated are in rough alignment on a bearing of 130°, and there is a crush belt to the south of the Gallery Rock at a slight angle from the same line and extending up the eastern wall of the main valley. Faulting, with an upthrow to the north, will explain the latter feature, and, incidentally, that of the upstanding rocks in the floor of the valley. Also the general absence of abrasion on these rocks, and specially on the southern face of Gallery Rock, indicates that they had not been subjected to glaciation for an extended period as upstanding rocks, and certainly had not, in such a form, experienced the glaciation at its maximum. Therefore faulting probably took place after the glacial period had commenced and before it had ended. This contention is supported by the recession of the glaciated walls of the valley above Gallery Rock as compared with the walls at the rock and further down the valley. One would have expected the surfaces to be continuous, and it is not so. It is possible, too, that other breaks in the valley walls, higher up, may be due to a similar cause, and the ice falls below Roberts Point may be attributed to the ice over-riding a barrier due to upfaulting to the north.

Another point illustrated by these glaciated valley walls is the supposed indication of a former level of the ice as deduced from the change in the nature of the vegetation up the mountain side above the ice. There is a lower belt where the trees are stunted, and an upper belt where they are larger, and it is usually assumed that the difference is due to the more recent abandonment of the lower levels by the ice. Mr J Mitchell, one of the guides at the glacier and a keen observer of natural history, has mentioned to me that the large trees correspond to a belt of crushed rock, probably due to the over-thrusting of the schist by the greywacke, the movement being from the east, and that the difference in growth of the trees may be due to the difference in the nature of the ground on which the trees have been established, the lower part being solid inhospitable schist, and the top the more kindly broken greywacke If the divergence in the character of the vegetation is really due to delayed evacuation of the lower levels by the ice as compared with the upper levels, then the lower belt of stunted trees extending along the valley walls should rise as steeply as the valley gradient, if not more steeply, and it does not do so. This is in favour of Mr Mitchell's contention, but the point needs further investigation.

Advantage was taken of this last visit to the Franz Josef to make an examination of the terminal face of the Fox Glacier, which lies in a sub-parallel valley 15 miles to the west. I had not seen

this glacier since 1905, when the terminal face was so indefinite that one could hardly tell where the river-bed ended and the moraine-covered ice began. At the present time the glacier has moved forward and shows features similar to those of the Franz Josef. River-bed material has been lifted up and pushed forward along its front, and in one case the ice has lifted this material with the trees on it still growing in position. The forward movement of the ice is indicated also by the movement of the upper layers over the lower layers along thrust planes. Behind the belt of river-bed moraine lies the true moraine, formed chiefly of angular greywacke rocks like those of the Franz Josef, but there is more of this in the case of the Fox, since a large fall occurred about three years ago from the end of Passchendaele Ridge, about two miles up the glacier, and this has made its appearance at the terminal face. There is another considerable fall of rock lower down the glacier on the eastern side. The greywacke forms a capping on the schist, and readily breaks away when the latter rock fails.

The stream issuing from the glacier lies almost entirely on the western side, and it comes from a large cave as a full-bodied river close to the margin of Cone Rock, a picturesque ice-scoured mass occupying a sub-central position in the valley, although at the present time no ice flows on its western side. The stream issues just opposite one of the cairns placed by the late Charles Douglas. I have been enabled to locate this through the kindness of the Chief Surveyor for Westland, who supplied me with a tracing of one of Douglas's maps filed in the office of the Lands and Survey Department. "On April 25th, 1894, at a bearing of 355 mag., the ice was 37 yards distant" (A. P. Harper, loc. cit., p. 330). From the vantage point furnished by this cairn the following sequence can be seen in the western edge of the ice:—

1. Moraine, covered in places with vegetation and lifted by ice, with one or two ridges of moraine pushed forward or carried forward by the ice.
2. Main ice of the glacier, as exposed at the actual outlet of the river, a section through this from the top showing the following:—
   - (iv) Moraine, composed of angular greywacke fragments.
   - (iii) Ice.
   - (ii) Wedge of moraine, over which ice is being pushed.
   - (i) Ice.

Here follows the river, and the ice (i) is apparently the same as that marked 1 above, though there may be other layers pushed forward between this and the terminal face further downstream in the middle of the valley, obscured by the coating of river-bed moraine. This suggests that sometimes a section in an old glacier deposit may be delusive, when moraine rests on gravel, and this in turn rests on tillite. It may not indicate two periods of advance with an intervening retreat, since the whole section may belong to the same phase.

Judging from the map kindly furnished me by the Lands Department, the present position of the terminal face is not as far advanced by about 100 metres as compared with its position as observed by Douglas in 1893-4. However, in front of the present face, nearly up to Douglas's recorded position, there are sink holes, one over 20 metres in diameter and 3 metres deep, which indicate that the ice has recently been under the river-bed or is actually under it now about 50 metres further down the valley. The whole attitude of the present terminal indicates that the glacier is at present advancing, though behind the face there are holes of considerable size, with streams issuing from them and running under the ice, which may herald an impending retreat.

A comparison of the records of the two glaciers suggests that the advance as well as the retreat is contemporaneous, seeing that Douglas's record of 1894 shows that both were well advanced. There is, however, the old photograph of the terminal face of the Franz Josef taken in 1867, which, according to Harper (loc. cit., p. 306), shows the terminal face from 80-100 yards further down the valley than it was in 1894, so that even in 1894 it may have been actually retreating. There are no data from the Fox to show any correspondence on the part of this glacier with the advance in 1908-9. At the present time the condition of the face in both cases is similar, but the Franz Josef probably will advance in the near future, whereas the condition of the Fox implies retreat. Much more detailed observation is necessary before correspondence in behaviour can be definitely established or disproved.

ADDENDUM.

NOTE.—During the year 1932 Mr H. L. Hume, B.E., of the Public Works Department made a number of observationss on the rate of flow of the Fox Glacier, and he has kindly placed them at my disposal. They are reproduced as follows:—

ANALYSIS OF OBSERVATIONS OF THE FLOW OF THE FOX GLACIER, SOUTH WEST LAND, NEW ZEALAND, ALONG A LINE APPROXIMATELY 60 CHAINS (1200 METRES) FROM THE TERMINAL FACE IN 1932.

All distances in metres.

Number of Station	Distance of Station from edge of bank.	Period of Observation, 1932	No. of days.	Total movement for period.	Average movement per day for each period.	Average movement per day over 57 days
1	65.6 m.	9th Oct. to 30th Oct.	21	4.03	.21	.19
		30th Oct. to 6th Dec	36	6.62	.18	
2	119.5 m.	9th Oct. to 30th Oct.	21	6.34	.30	.27
		30th Oct. to 6th Dec.	36	8.90	.25	
3	196 m.	9th Oct. to 30th Oct.	21	9.30	.44	.375
		30th Oct. to 6th Dec	36	12.04	.34	
4	248.4 m.	9th Oct. to 30th Oct.	21	10.21	.488	.49
		30th Oct. to 6th Dec.	36	18.11	.50	
5	296.8 m.	9th Oct. to 30th Oct.	21	11.28	.537	.54
		30th Oct. to 6th Dec.	36	19.51	.543	

This result indicates a somewhat low rate of speed, but it is possible that it may be explained by the line of stations being taken across a somewhat flat reach of the glacier. Mr Hume has kindly offered to continue his observations and also to keep records of the position of the terminal face, and other features of interest in connection with the Fox Glacier.

View from Peg 1 looking south, showing the retreat of the face from valley wall Wilson Rock is almost visible on extreme left of picture.

Face p. 322

Acid Rocks of the Taupo-Rotorua Volcanic District.

By P. MARSHALL.

[*Read at meeting of Wellington Philosophical Society, October 25, 1933; received by the Editor, November 3, 1933; issued separately March, 1935.*]

CONTENTS.

FOREWORD.

IN order to avoid difficulty and confusion in nomenclature in speaking of the rocks that are dealt with in this paper, this preliminary statement is made. These rocks are regarded as formed by an eruptive process similar in its nature to that which was described by Fenner as acting at Katmai in Alaska. In other words, they are thought to have been deposited from immense clouds or showers of intensely heated but generally minute fragments of volcanic magma. The temperature of these fragments is thought to have been so high that they were viscous and adhered together after they reached the ground. Since this type of rock mass has a wide occurrence in New Zealand, but has not been recognised before except by Fenner, who calls it "indurated sand flow rock," it appears that a new term is required for its designation. Rocks which are thought to have been formed in this manner are here called Ignimbrites.

The following quotations will show that these ignimbrites are different from the vitric tuffs described by Pirsson (Pirsson, 1916, p. 894): "The expansion of gas and rupturing began in a liquid medium and falls as a rigid glass. We do not know, of course, the

exact march of events between these points; but it is clear that the magma ruptures into separated masses of different sizes as the volume of mingled gases and molten glass rush out of the conduit. The separated masses are themselves swelling and flying apart into smaller ones as they ascend, and this continues until the stiffening of the glass and the lessening of the expansion of the gas through cooling bring the process to an end."

It is clear from this extract that Pirsson, who is the originator of the term "vitric tuff," did not in this vivid account of the eruption of tufaceous matter visualise the idea of the particles of melted glass, suspended in the gases that had emanated from the volcanic matter, and retaining a temperature so high that they remained viscous even after they fell. In other words, his term "vitric tuff" does not comprise ignimbrites It would seem that the possibility of particles of volcanic matter retaining their viscosity in minute sizes and in immense volume until they had actually fallen was not imagined until after Fenner's account of the Katmai eruption

I wish to express my deep thanks to Mr E. T. Seelye, of the Dominion Laboratory, who with the permission of the Dominion Analyst, Mr W Donovan, made a complete analysis of ignimbrite (tridymite rhyolite) from Waihi. He also was good enough to make many experiments on the effect of submitting ignimbrite material to temperatures as high as 1050 degrees Centigrade.

Previous Descriptions.

The earliest explorers of the North Island of New Zealand at once recognised the wide occurrence of volcanic rocks. Dieffenbach said: "We passed cliffs of pumice stone. . . . In some places there was a greyish lava of a striped and variegated appearance resembling jasper." (Dieffenbach, 1843, vol. 1, p. 371.)

Taylor remarked: "There is much obsidian and pumice near Taupo." (Taylor, 1855, p. 244.)

Hochstetter made many observations and collected a number of specimens in this region. In particular, he published a sketch of Horohoro mountain near Rotorua (von Hochstetter, 1864, p. 106). Horohoro has a special interest as this hill illustrates better than any other in the district the flat-surfaced, steep-sided forms which in greater or less degree are characteristic of the elevations composed of rocks that are the main subject of this paper. In the map on page 20 the volcanic rocks are classified by Hochstetter as rhyolite lava. This classification is based on the work of Zirkel, who was entrusted with the examination of the rock specimens that were collected by the expedition. He distinguished between glassy, spherulitic, and banded types of rhyolite as well as tuffs.

Hutton, in 1889, in a paper on the eruptive rocks of New Zealand (Hutton, 1889, p. 115 et seq.) described a number of the rocks as enstatite rhyolite and enstatite trachyte.

Rutley, in the Quarterly Journal of the Geological Society of London (Rutley, pp. 449-469, and 1901, pp. 493-510) gave petrological descriptions of a number of these rocks, mainly from the Waihi district. He describes at some length the various types of spherulitic structures that are found in them. In the latter paper (Rutley, 1901, pp. 496-7) he classifies two of the rocks as tufaceous rhyolite lava. He remarks on the probable similiarity in origin to those of the Dufton Pike (Rutley, p. 509).

Sollas has described a number of these rocks in detail. It is clear, however, from p. 23 that he has difficulty in deciding whether some of the rocks are flow lavas or tuffs. (Sollas, 1905, p. 23.)

More recently, Morgan, and later Henderson and Bartrum, and afterwards Morgan again, have published descriptions in the Bulletins of the New Zealand Geological Survey (Morgan, 1912; Henderson and Bartrum, 1913; Morgan, 1926). A good list of references is given by Henderson and Bartrum in their publication, p. 70. They give a useful summary of the statements that have been made by various authors in regard to certain of the rocks that are found near Waihi.

Within recent years these acid rocks have been mentioned in several publications (Henderson and Ongley, 1923, p 56): " Rhyolitic tuffs in places hundreds of feet in thickness cover large areas." The source " undoubtedly lay to the east." The rocks consist of " very fine particles of glass containing glass flakes in abundance as well as crystals and fragments of sanidine, albite, and oligoclase. Quartz crystals are rare." (L. I. Grange, 1927, p. 39): " Well cemented rhyolitic tuff occurs in the Ongaruhe Valley "; and in the Annual Report of the Geological Survey (Grange, 1927-28, pp. 8, 9): " The rhyolitic tuff which is the predominant rock . . . since the surface of this deposit except where disturbed by later movements is almost flat, it is thought that the fragmental material was laid down in water." J H Williamson speaks of cemented and well-jointed rhyolite tuff. (Williamson, 1930, p. 9.)

The author, in 1929 (Marshall, 1929, p. 31) wrote. "A vitric tuff that occurs widely in the Waikato district might be used with advantage for building purposes; it is relatively fine grained, and is mainly formed of minute particles of glassy rhyolite which were ejected by the expansion of steam in melted volcanic rock and fell back to the ground while still hot, and united together sufficiently to form a moderately compact rock. With the small fragments of glass there are large numbers of quartz and felspar crystals more or less rounded in form."

In 1931 the author read a paper before the Wellington Philosophical Society giving descriptions of these rocks and of the supposed eruptive actions to which they were due. These were regarded as probably similar to those of the Valley of Ten Thousand Smokes at Katmai in Alaska. This eruption was described by C. N. Fenner, who mentions an " indurated sand flow rock " which seems to be of the same nature as some of the rocks that are described here. The most characteristic feature of this eruption was afterwards called the " nuée ardente Katmaienne " by Lacroix.

This address, being then incomplete, was not published; but a short abstract of part of it was printed. (Marshall, 1932, p. 198.) The present paper is in effect the address of 1931, but many additions and some alterations have been embodied in it.

In the references that have been cited above no mention is made of flow structure. So far as these rocks are concerned, the flow structure is here interpreted as due to the pressure of the overlying tuff directly after its deposition. The structures called in this paper radial and pectinate are not mentioned, though the latter is particularly prominent at Ongaruhe and elsewhere in that neighbourhood. The rock is described by Grange as cemented, and the reference to deposition beneath water seems to imply that cementation by material dissolved in water is regarded as operative. There is no reference to welding.

H. T. Ferrar says: "The rhyolitic material like that ejected at Katmai in Alaska shows no distinct craters and was probably erupted through a number of vents, not one of which has at present been located. . . . The tuff usually contains angular fragments of obsidian and pumice, which being hot and sticky when erupted, adhered to form a massive rock." (Ferrar, 1930, p. 3.)

Occurrence.

When the size of the North Island of New Zealand is considered, it can be said that these acid rocks or ignimbrites are found over a wide area. On the Wanganui River near Taumarunui and on the eastern side of Lake Taupo they reach their southern limit. The northern extremes are at Mercury Bay in the Coromandel Peninsula and at Mercury Islands, and in the Hinuera Valley in the Middle Waikato region. In the west they reach to Te Awamutu, and even to Puketiti, 15 miles west of Te Kuiti (specimen kindly given to me by Mr Ferrar). In the east they are found as far as Tauranga, the lower Rangitaiki, and almost to Tarawera in the Mohaka Valley. Within this wide area, however, they do not constitute the striking volcanic cones which are the most conspicuous feature of this region. The several large mountains Ruapehu, Ngauruhoe, Tongariro, Pihanga, Maungatautari, Tauhara, and Edgecumbe are none of them composed of acid volcanic rocks, but of andesites of various types. The area over which scattered outcrops of acid rocks occur amounts roughly to 10,000 square miles. This is the "rhyolite plateau" of New Zealand geology.

Physiographically it may be said that within this district the outcrops of the ignimbrite rocks can generally be recognised in the field, even before they are closely approached. Usually they have a surface that is approximately level; while the margin of the areas are markedly precipitous. Here massive outcrops of rock are frequent. These ignimbrites have in nearly every case a coarse prismatic jointing, and, as their nature, though not extremely hard, is distinctly tough and they are resistant to atmospheric action, the huge columns stand out in the most striking manner. Little broken rock is shed from them, and the outcrop thus acquires a noticeable and striking form. Plate 69, figs. 1, 2, 3.

This condition is most arresting on the margins of the old Waikato Valley at Hinuera, and is well seen in the present gorge of this river at Arapuni. An illustration of this most characteristic type of outcrop is given by Morgan. (Morgan, 1913, Pl. X.) A striking illustration in Reise der Novara, p. 80, of the columns at Motuara Island. Mercury Bay, and entitled "Saulenformige Trachyt" is, however, misleading. The actual locality is at the north end of Great Mercury Island. The rock is hypersthene basalt. Everywhere within the area of these volcanic acid rocks there has been some activity since the ignimbrites themselves were deposited. One phase of this activity has been the covering of the ignimbrites with a superficial coating of pumice of varying but often of considerable thickness. This material, too, covers all the country in the lower land, between the hills that are formed of ignimbrite rocks. Another phase of the later volcanic action has been the formation of the great cones which attain their culminating point in Mount Ruapehu, which has an altitude of almost 10,000 feet. These cones are with few exceptions formed of hypersthene andesite.

In contrast with these andesitic cones it is a fact that there are no cones of acid rock in spite of the wide occurrence of this type of material. The highest point at which this material is found is perhaps Mount Tarawera at 3600 feet, but no full petrographic description has yet been given of its occurrence in that locality. It is, however, certain that acid rocks were not concerned in the great eruption of that mountain in 1886, except as ejected blocks of previously consolidated material. Tarawera has not a true conical shape, and there are no lava flows on its flanks. The rock emitted during the eruption of 1883 was basic andesite. Wherever these ignimbrites have been intersected by stream courses steep narrow gorges have been developed. This is clearly a result of the pronounced prismatic jointing in the absence of horizontal division planes; but it is partly due also to the remarkable chemical resistance of the rock to the action of the atmosphere. Where a larger river intersects an outcrop of these rocks massive blocks are from time to time carried away and are transported far down the river valley. Large blocks of this nature are conspicuous objects in the Wanganui River as much as forty miles below the outcrop of any acid material. This again emphasises the unusual toughness of the rock, in spite of its softness, and its comparative freedom from separation planes and irregular joints.

The thickness of the ignimbrites varies considerably. It is unusual, however, to find any single outcrop with a greater thickness than 200 feet; though this is certainly exceeded at Ongaruhe, and at Mututere on the east side of Lake Taupo, and on the coast south of Mercury Bay. In the Waikato Valley 30 miles south of Arapuni it is at the least 500 feet thick. Plate 70, fig. 1. On the other hand, in the Hinuera Valley the thickness is 60 feet, and in general it appears that formations of the ignimbrites are not often thicker than 100 feet.

The eruption of ignimbrites probably extended over a considerable period of later Tertiary and Post Tertiary time at irregular intervals.

PHYSIOGRAPHIC FEATURES OF THE FIELD OCCURRENCE OF THE IGNIMBRITES IN THE NORTH ISLAND AREA.

Before considering the detailed mineralogical and microscopic characters of the ignimbrites, it is as well to mention some physiographic and field facts with regard to the disposition and occurrence of these rocks in general. Remarks that may be made under this head must not be considered as applicable in all respects to every outcrop of these rocks.

(1) It has already been stated that the upper surface in many of the localities where the rocks occur approaches the horizontal plane. The lower surface, too, is generally regular and shows little or no roughness such as that which is generally seen on the lower surface of an ordinary lava flow.

(2) These ignimbrites appear to be never definitely related to any volcanic cone. Although they occur over such a wide area, there is no culminating point which can be regarded as the point from which they were ejected. Actually, as previously stated, some of the thickest of the deposits that the author has seen were at the south end of the area at Ongaruhe, at the north end at Mercury Bay, and on the east at Motutere on the east side of Lake Taupo. If there is any distinction to be made, it would appear that the greatest thickness of deposits is to be found in the marginal portions of the area, though at present no importance can be assigned to this distribution, even if it is rightly stated.

(3) No scoria was found anywhere on the upper surface of these rocks. Molten material of this highly siliceous nature is notably viscous; and in all cases it is probable that it contains large quantities of water vapour. These are well known to be the conditions that particularly promote the development of scoriaceous matter. The very general occurrence of pumiceous matter of a highly vesicular nature emphasises this in New Zealand. The entire absence of scoria on these rocks is therefore a notable fact. The covering of pumice that is generally found on them has certainly not been developed from the ignimbrites; but it has probably been projected over large distances by violent explosive eruptions of the Krakatoan type. The fragments of pumice never show any attachment to the surface of the ignimbrite on which they rest. They are more or less rounded as though from attrition, and have no resemblance to the scoriaceous development of a lava surface. It is abundantly clear that the pumice has fallen in showers onto the surface of the ignimbrites after their formation and by independent eruptive action.

(4) The lower surface of these acid rocks wherever it has been observed, notably at Arapuni, has been found to differ from the upper parts but little, in any respect except coherence; for the very base is formed of incoherent matter which actually consists of minute

particles of volcanic glass among which there are some crystals of felspar and quartz of relatively large size. In this part of the rock, too, there is no development of scoriaceous matter. The grading of this fine matter which forms the base of the ignimbrite at Arapuni is as follows:—1/30″–1/40″ 6.60, 1/40″–1/50″ 3.90, 1/50″–1/60″ 2.33, 1/60″–1/80″ 3.77, 1/80″–1/100″ 4.73, 1/100″–1/200″ 18.40, <1/200″ 59.60%. Examination of microscopic preparations shows that this is practically the grade of the particles throughout the rock also, even where it is solid and compact.

(5) The regular jointing and consequent display of columnar structure demands exceptional conditions for its development in flow rocks It is necessary that there should be a condition of complete rest and stillness whilst cooling and solidification are in progress. The attainment of such conditions in a lava flow implies great fluidity and relatively rapid flow before a necessary containing basin is reached It has not yet been shown that any of the occurrences of these ignimbrites are situated in such pre-existing basins. Their actual positions perhaps point to the reverse. At any rate, great fluidity for some time after the emission of the molten material would be required in order to account for the present position of the rock masses and for their habitual wide extension. Yet in the case of these rocks chemical composition is such as to preclude the possibility of such great fluidity as is obviously required: for the percentage of silica exceeds 70.

When all of these facts of field occurrence and of detailed structure are considered, it appears certain that these extensive formations of acid rocks were never real lava flows. It is therefore misleading to speak of any of them as rhyolites. Before expressing any other opinion as to their origin, however, it is necessary to describe in some detail the main facts of their lithological and petrological structure.

Lithological Nature of the Ignimbrites.

A very great variety of lithological features is to be seen even on the most cursory examination of a series of hand specimens of these rocks. The type that is generally called wilsonite is perhaps the most arresting. In this rock there are lenticules or ovoid patches of dark coloured material, usually glass, often three or four inches long, which are embedded in a matrix of stony appearance. This structure appears to be typically eutaxitic, as usually defined, though this term was first applied by von Fritsch and Reiss to nephelinitoid phonolites in 1868. Yet the whole rock sometimes has a vitreous lustre on a fractured surface. The transition from this extreme form to the completely fine and even grained lithoidal or stony rock is probably a gradual one; though it is true that no complete transition has yet been observed in any one locality. This lithoid or more finely textured type of rock has generally been called rhyolite, though Henderson, Grange, and others have recently written of occurrences at Ongaruhe and elsewhere as tuffs. This type of rock has usually a white to grey colour and has always rather a harsh feel. It has a very general occurrence throughout this area.

Even in hand specimens it can always be seen that all these rocks contain a large number of glassy crystals of felspar and some of quartz. Usually the rock breaks round the crystals, not across them. The rock is, however, relatively soft, though it does not fracture with ease, as it is quite tough. Even with a lens the stony base cannot be resolved into any particular components. At or near the under surface of this stony lithoid rock the material may have a darker colour; and as at Arapuni it may have a vitreous lustre; but for the most part it is notably granular, and may in its upper portion become almost earthy. A sample of the surface material at Arapuni was broken down with a rubber pestle under water and was found to have the following grading:—

$> \frac{1}{40}''$	16.34
$\frac{1}{40}'' - \frac{1}{50}''$	4.17
$\frac{1}{50}'' - \frac{1}{60}''$	3.00
$\frac{1}{60}'' - \frac{1}{80}''$	2.22
$\frac{1}{80}'' - \frac{1}{100}''$	3.78
$\frac{1}{100}'' - \frac{1}{200}''$	12.65
$< \frac{1}{200}$	54.37

Although thus very generally similar over a wide area, a difference in colour, or compactness, or texture will often distinguish the samples from different localities. Thus specimens from Hinuera will often contain small fragments of real rhyolite rather than glass, somewhat vesicular indeed, but far more compact than pumice. Specimens of a fine-textured ignimbrite from Ongaruhe have a yellow or even an orange tint. Those from Arapuni are almost white. The wilsonite from Putaruru is pink; while that from Owharoa is pale grey, and samples from Waikino are light brown in colour. All of the great outcrop at Motutere on the eastern shore of Lake Taupo is a brownish grey in tint.

The actual extent of any one of these outcrops is not easy to discover. The heavy superficial covering of pumice obscures them for wide distances over the surface of the country, and it is only where streams have cut valleys through the pumice beds above them that the underlying ignimbrite can be seen. It can hardly be asserted that the stream valleys really delineate the boundaries of a single area of these acid rocks, especially in the absence of detailed petrographic work, which is at present wanting. The isolated and steep-sided hill Horohoro, the form of which has generally been ascribed to faulting, is a striking feature of the country on the south-west of Lake Rotorua. Hochstetter originally took this view of its origin. (von Hochstetter, 1864, p. 196.) It is, however, possible that Horohoro is the scene of a separate ejection of ignimbrite; though such a suggestion is at this time a pure hazard, for we have no detailed description of the hill, nor of the rock of which it is formed, at present.

The general impression gained in the area over which these acid rocks occur is that any one lithological type has not a wide lateral extension. The margin of an ignimbrite wherever it is

exposed has, with a few exceptions, the form of steep cliffs; but it never has the heavy scoriaceous slopes that mark the termination of a true lava flow. While it is true that these exposures are always on the margin of areas of erosion, the impression is nevertheless conveyed that these rock masses terminate rather abruptly; though originally they may probably have passed laterally into softer and more incoherent matter which was an easy prey to the agents of erosion and was soon removed.

Petrography of the Ignimbrites.

Wilsonite type (Fig. 2, plate 66; figs. 1 and 2, plate 67.)

The nature and origin of the wilsonite type of ignimbrite have been much discussed. The specimens that were first described by Rutley were called by him pumice tuffs. (Rutley, 1899, p. 457, also 1900, p. 494.) Sollas, in the volumes on the Hauraki Goldfields (Sollas, 1905, vol. 1, plate facing p. 66, pp. 123, 124) remarks: "I am quite prepared to accept it as having once been in a state of flow." But in a footnote: "Some of the specimens are formed of material that has fallen through the air." Further (Sollas, 1905, vol. 2, p. 46): "If, as the field evidence seems to suggest . . . this is a flow rock, then the form of the shreds of glass can no longer be regarded as characteristic of a tuff." Again (Sollas, 1905, vol. 2, p. 46): "The microscope offers no disproof of the theory that this rock was once flowing." He also states that the rock had undergone an extreme amount of internal brecciation. Bell and Fraser (1912, p. 48): "The rock is evidently a flow with a considerable amount of internal brecciation." Henderson and Bartrum (Henderson and Bartrum, 1913, p. 72, analysis p. 73) review previous opinions and state that they incline to the view that the rock is a tuff and was deposited very close to the point of ejection; but that its components were in the viscous state. Arguments for and against this idea are given in full. This opinion seems to have been accepted by Morgan (Morgan, 1924, p. 65), though he had previously stated that the rock was a lava, not a tuff (Morgan, 1911, p. 273). Morgan sometimes refers to the rock as displaying brecciated flow structure. It seems that the rock was first mentioned by Cox (Cox, 1882, p. 20): "A rhyolitic rock containing a mixture of pumice and obsidian." A similar description was given by Hutton (Hutton, 1889, p. 116).

All of those that have studied typical wilsonite from Waikino or Owharoa are agreed that it is composed of relatively large fragments of glass embedded in a matrix of stony appearance in which many clear and colourless crystals of felspar and quartz can be distinguished. Actually the stony matter is found to consist mainly of small shreds of glass which may show a parallel arrangement—the so-called flow structure. Most of these small fragments of glass are colourless, though some of them have a colourless border around a brown core in which the colour seems to be due to numerous minute globules or granules too small to identify, though they may be gaseous. The felspar crystals are generally fractured or merely broken pieces, and are sometimes rounded. Oligoclase is the most usual species.

though there is a little sanidine, and some andesine. The grains of quartz are rounded and show no crystal faces. Small crystals of hypersthene are common, and they show crystal faces. Sometimes there is a little biotite, or greenish brown hornblende. The large fragments of glass in wilsonite are found when studied in microscopic preparations to be traversed by many capillary air spaces.

Hinuera type. (Plate 69, fig. 3; plate 62, fig. 2.)

In this type of the rock the field occurrence has massive columns which attain as much as eight feet in diameter and sometimes they are forty feet in height. The rock in the typical locality at Hinuera has a buff colour, but fragments of conspicuous white rhyolite that is too compact to call pumice are noticeable and frequent. These may be three or four inches in diameter, but they are not lenticular like the glass fragments in the wilsonite, and they are stony rather than glassy. In microscopic preparations the fragments of rhyolite are seen to consist of colourless glass traversed by numerous thin capillary pores. They are embedded in material of a fine texture in which numerous broken crystals of felspar and a few of quartz can be seen. As in many of the other rocks there are occasional narrow crystals of hypersthene, and rarely of hornblende. The matrix in which they are embedded is of a pale yellow tint. When studied in microscopic preparations the matrix is found to consist of irregular but largely linear glass shreds lightly welded together. Here again they are often brown in the centre, though this feature is far more noticeable in the larger fragments than in the smaller.

It is suspected that the colour is due to densely crowded minute gas globules, though the small size prevented them from being clearly resolved under the microscope except in a few instances. (Plate 62, fig. 2.) In this rock there is no flattening of the glass fragments, and no flow structure has been observed, but only a small portion of the outcrop has been examined at present. There appears to be a strong tendency for the brown fragments of glass to lose their colour In the upper part of this formation in the Hinuera valley, that is at any point more than ten feet above the base, the particles have all lost their vitreous nature and show a rudimentary axiolitic structure. Even the extent of the Hinuera deposit is at present unknown. Certainly it occurs over a distance of at least three miles on both sides of the Hinuera valley; but how far it extends backward from the side of the valley has not yet been determined The universal covering of pumice, here as elsewhere, offers very considerable difficulty in the details of field work.

This Hinuera type of ignimbrite occurs at Mercury Bay and in the valley of the Mangakino River, a tributary of the Waikato, as well as in the Hinuera valley and many other localities.

Paeroa type. (Plate 62, fig. 1.)

This rock is of a brownish colour and is less coherent than the other types—in hand specimens it seems almost earthy. It contains fragments of a great variety of volcanic rocks, sometimes as much as four inches in diameter. However, the earthy appearance is

actually misleading; for even when boiled in sulphuric and hydrochloric acids there is no distintegration, and the rock actually gains in hardness and solidity from the treatment. The lapilli embedded in the rock consist of different varieties of rhyolite, and andesite, which are not glassy, but are already well crystallised. Sometimes there is a little alteration, and some of the ferro-magnesian minerals may be partly chloritised; in this respect resembling the rock from the Okaro crater as described by Hutton. (Hutton, 1889, p. 137.) Despite this structure, the rock in the field has a well-marked coarse columnar development.

When the rock is studied under the microscope, the usual crystals of felspar and quartz are found, with their usual colourless transparency. As in other localities, there is some hypersthene in small columnar crystals and a little hornblende, and occasionally pale green augite; but in the fragments these may be converted into chloritic and serpentinous substances. In the andesite there are in addition a few grains of pale green augite such as Hutton recorded from Atiamuri. The fine portion again consists of shreds of glass, which actually in this case have undergone some amount of crystallisation since they were deposited On their inner margin there is a fine felt of minute felspar needles which at times extend a third of the distance across the shred. The glass shreds do not bend round the crystals, as can occasionally be seen at Hinuera; but the solidity of the rock shows that they are welded together to some extent, and the partial crystallisation shows that their temperature was high when they were deposited.

This type is typically shown in the Paeroa Range on the west side of the Rotorua–Taupo road, between Waiotapu and the Waikato River.

Arapuni type. (Plate 63, fig. 1.)

This is a typical fine textured rock of the ignimbrite group. It is fine and even grained; but has a harsh surface. This type is always light coloured, grey to creamy, or even pale yellow. Conspicuous clear glassy crystals of felspar and quartz can always be distinguished even in hand specimens.

Samples of this type of rock collected in the underground workings of the Waihi mine were called by Morgan "tridymite rhyolite" because of the wide occurrence of tridymite in that locality, though it is revealed by microscopic examination only. (Morgan, 1911, p. 273.) Such study also shows that the felspar is generally triclinic, oligoclase being the most usual species. Sanidine occurs rather rarely, and all of the felspar crystals are usually incomplete with jagged margins. Often they are mere fragments. Quartz is far less frequent than the felspars. Hypersthene, hornblende, and biotite are sometimes found, and occasionally small crystals of magnetite. The tridymite occurs very generally, sometimes as small rosettes in cavities, but more frequently along the centre line of axiolites, but also sporadically among the finer elements of the rock.

The mineral tridymite appears to have been first recognised by Rutley in these fine grained rocks. He remarks of them in general: " Reheating of already solidified lavas has been, as we have frequently had occasion to remark, a by no means uncommon feature in the history of these rocks." He also speaks of " a globulitic devitrification " in connection with this. (Rutley, 1899, p. 465.)

Sollas disposed of this idea of refusion so far as certain features of the more coarsely spherulitic rocks are concerned; but substituted for it the explanation that a certain peculiar decomposition had taken place. (Sollas, 1905, p. 121, vol. 1.) While Rutley seemed to regard the fine grained rocks as lava flows, with two exceptions which he called " tufaceous rhyolites." Sollas treated them all as lavas; and this opinion was apparently held by Morgan, Henderson, and Bartrum also. (Morgan, 1912, 1913, 1924.) In the last of these bulletins Morgan gave a peculiar explanation of an unusual feature of these " tridymite rhyolites." All observers had noticed the occurrence of triclinic felspars almost to the exclusion of monoclinic forms, and Morgan had previously recorded the presence of carbon in some of these types. In the publication quoted he refers to the crystals as " clearly showered on the lava, or surface derived, like the fragments of carbonised wood previously mentioned." (Morgan, 1911, p. 67.) It is merely remarked at the moment that the common occurrence of plagioclase, and the far less common occurrence of quartz, suggests that the magma from which the ignimbrites were derived was of the nature of a highly acid dacite.

This type has its most typical development at Arapuni. It is also found at Ngutuwera and widely near Waihi.

In all of the samples of this fine-grained type or arapunite that were examined by Rutley, Sollas, Morgan, Henderson, and Bartrum, it seems that fragments of glass were practically absent. In other parts of the district, however, it is found that glass shreds and curved glass fragments of minute size compose the whole of the fine grained matrix of the rock; though in hand specimens the rocks can hardly be distinguished from the typical " tridymite rhyolites " of Waihi. Though actual shreds and fragments of glass are not seen in these " tridymite rhyolites," there can be no question that the ill-defined axiolites, which constitute their main material, were originally glass shreds; though in them incipient crystallisation was developed at the time of their deposition.

These minute particles of glass at Arapuni always have their greatest dimensions in the horizontal plane. They are pale brown in colour, and in section are seen to bend round the corners of the felspar crystals, thus giving the typical appearance of the so-called flow structure. (Plate 63, fig. 1.)

Fayalite occurs in types of these acid rocks at Ohena Island, Mercury Bay, at Pohaturoa, Atiamuri, and is perhaps altered to magnetite in many other localities.

The Origin of Ignimbrites.

Before entering upon any further discussion of the composition and structure of these rocks in different outcrops, their origin may be considered. It is as well to take the simplest case first, such as the rock which occurs at Arapuni. Here the lowest part of the rock, above the basal layer of fine sand, consists of the usual crystals of felspar and quartz with a little hypersthene which are embedded in a matrix of fine shreds of glass, the particles of which have that form and arrangement which are commonly considered as characteristic of flow structure, and have been so interpreted in a large number of instances. In many cases the phrase " corrugated flow structure " has been applied to them. The very nature of the rock, however, precludes the possibility of mass flow, for it consists of minute but quite distinct individual fragments of glass which are lightly fused together. It comes, however, within the range of similar rocks that have been described by Iddings. (Iddings, 1899, part 2, p. 404, and pl. 50, A, B, and C.) This kind of rock is stated by him to be formed of collapsed pumice. It is here considered, however, that the uniform nature of the rock over wide distances, the absence of all remnant of pumiceous condition, the absence of a sufficient grade for flow before the assumption of the pumiceous state, the occasional presence of carbon, the obvious occurrence of minute separate fragments of glass, and the absence of any other evidence of collapse of pumice in rock masses throughout the district, individually and collectively, preclude the application of such an explanation in this case.

It is thought that the observations which have recently been made by Fenner in regard to the burning sand flow in the Valley of the Ten Thousand Smokes afford a satisfactory explanation of the deposit of these ignimbrites. A similar explanation has already been made by the author in a pamphlet on the building stones of New Zealand. (Marshall, 1929, p. 31.) This was before Fenner's statements in explanation of the " indurated sand flow rock " had been noticed. (Fenner, 1925, p. 198, and footnote.) At the Katmai eruption, as described by Fenner, the material of the sand flow was of such a high temperature when ejected that the fragments of glass of which it was composed, in places, welded together and thus formed the " indurated sand flow rock." The actual mechanical state of this sand flow is compared by Fenner to a cloud of heated basic carbonate of magnesia in a finely powdered state. Lacroix, however, suggests that the condition of the erupted material was more properly to be compared with that of milk boiling over. (Lacroix, 1930, p. 460.)

That a mixture of incandescent powder suspended in a heated gas behaves as a fluid is now generally admitted. Lacroix states that the nuée ardente from Mount Pelée flowed towards the sea with the velocity of 159 metres per second, equivalent to almost 360 miles per hour.

It is clear that a velocity much less than this would enable a " nuée ardente " to rise far on the flanks of an opposing acclivity and to cover an area of deposition different in extent and configuration from any that could be associated with an ordinary flow

of a liquid. Though it would seem that none of the ignimbrites in New Zealand flowed down such a declivity as partly caused the high velocity of the nuée ardente at Mount Pelée (the nuée ardente Peléenne of Lacroix) it yet appears to be a fact that the material of the " nuées ardentes " from which the New Zealand ignimbrite rocks were formed was of far finer grain than that at Katmai. This in itself may be supposed to imply a more rapid evolution of gas and consequently a higher initial velocity than that of the material of the Valley of Ten Thousand Smokes. I am indebted to Dr Fenner for a sample of his " indurated sand flow rock " which has enabled me to make an actual comparison which reveals a close resemblance to the New Zealand ignimbrites. At Arapuni there is a layer of fine sand three inches thick beneath the ignimbrite. This is regarded as the portion of the fiery cloud that was cooled rapidly by contact with the atmosphere and the ground. Immediately above this sandy layer the rock has a glassy lustre, and microscopical examination shows that the glassy particles are lying with their longer axes horizontal and were compressed by the weight of the overlying material and welded together into a moderately compact glassy rock. The particles of glass were bent round the angles of the solid crystals in such a manner as to give the effect of actual flow movement. It is thought that this may be the origin of the flow structure that has been described in many rhyolite areas. It is also suggested that this explains the features that were ascribed by Iddings to the collapse of pumiceous structure in the Yellowstone region. When the glassy fragments are of conspicuously unequal size as in the wilsonite the resultant rock would give the impression of " brecciated flow structure," a phrase which with " corrugated flow structure " is so widely employed in descriptions of rhyolitic rock. It has always seemed to the writer a matter of extreme difficulty to comprehend the physical conditions that are described as the cause of the development of this structure. A brief description of this structure and its origin is given by Holmes in these words: "A term describing lavas in which fragments of partly solidified magma produced by explosion or flowage have become welded together or cemented by the still fluid parts of the same magma." (Holmes, 1920, p. 100.)

Even if such a structure were developed in the manner described, it appears to the writer that a continuation of the flow would quickly change it into a highly streaky form of rock or would entirely destroy the structure described. It is thought that the relatively large particles of glass, incandescent at the time of deposition, which occur in large numbers in the wilsonite, imply rather less gaseous emanation and expansive force than is evidenced by the structure of the finer-grained ignimbrites. However, the super-hurricane velocity of nuées ardentes as described by Lacroix would allow of even these large particles being carried and distributed over wide distances. Whether a wilsonite in its lateral portions gradates into an arapuni type or other finer material on the margins of its area has not yet been determined. Unfortunately, the difficulties of field work have

up to the present prevented the necessary investigations for solving this question from being made. It is, however, the author's opinion that such variation does not occur.

Lacroix has defined the nature of the material of a nuée ardente and its physical condition in the following words (Lacroix, 1904, p. 203):—

Les nuées ardentes sont constituées par un mélange intime, une sorte d'émulsion des matériaux solides en suspension dans de la vapeur d'eau et dans la gaz, portés les uns at les autres á haute temperature.

P. 350: Chacune des parties ou des particules solides qui les constituent rayonne de la chalure et doit être entourée par une atmosphère de gaz et de vapeurs extrèmement comprimée au début mais se dilatant rapidement; c'est cette atmosphère qui, empêchant les particules solides de se toucher, maintient l'ensemble dans un état de mobilité permettant de couler sur les pentes presque a la facon d'un liquide.

P. 358: Il est donc probable que l'explosion est due a la brusque détente de la vapeur d'eau contenue dans le magma . . . on doit admettre que la tension des gaz inclus dans celui-ci augmente a mesure que sa consolidation s'effectue sans l'influence du refroidissement.

Rudimentary Crystallisation in some Ignimbrites.

It has already been stated that the lowest part of the ignimbrite at Arapuni is a fine sand consisting of minute glass shreds, and that overlying this there are eight or ten feet of a compact rock that has a vitreous lustre. The upper portion of the fifty feet of thickness of this Arapuni type changes gradually into a rock that in hand specimens has a more stony appearance, but also a more pulverulent structure. With microscopic examination it is found that in this portion the small glass shreds are less transparent because of a rudimentary crystallisation which has been set up. While it has not been found possible to identify the actual minerals that have been formed by this action, comparison with samples from other localities in this district in which the structure is more fully developed indicates that felspar and tridymite are present in an association such as that which will be subsequently described as occurring at Ongaruhe and which is typical of a number of the rocks of this district. The gradual change from the more compact and distinctly glassy condition of the shreds of the lower part of the outcrop at Arapuni to the less compact and slightly crystallised condition of those of the upper part is probably due to difference of temperature originally, rate of cooling, evolution of gaseous matter, and decrease in the amount of pressure. At the base, cooling would have been relatively rapid because of the proximity of the cold substratum on which the erupted material rested; the dissolved gases in the material would have become disengaged at once; and the pressure of the overlying matter would have been considerable. These conditions would tend to promote the formation of a relatively rigid rock. The

material ten or twenty feet higher up may have had a slightly lower temperature. This, however, is too uncertain to provide any basis for definite conclusions. Even if the temperature of the material when it was emitted had been the same, the conditions of cooling before the point of deposit was reached may have been very different. After deposition the rate of cooling was probably not the same as that of the lower material. The fall in temperature was probably less rapid because of the greater distance from a cooling surface. Heated gases would probably be emitted from the lower part of the ignimbrite for a considerable period and would maintain the upper part at a higher temperature than the lower. At the same time, the uprising of the gaseous matter might tend to prevent the small paricles of glass from welding together as readily as they would if they were undisturbed, an effect that would be augmented by the smaller pressure in this higher portion. It is worthy of note that Lacroix quotes experiments of Brun which show that deformation of particles of volcanic glass of an andesitic nature takes place at a temperature of 938 degrees centigrade and that the glass can be drawn into threads at 1050 degrees. (Lacroix, 1908, p. 54.) He further states that the formation of spherulites will take place in such glass until the temperature has fallen to 460 degrees. It seems reasonable to think that in these highly siliceous and viscous materials development of rudimentary crystalline structure would take place very slowly. Consideration of these results leads to the opinion that the temperature of the glass fragments when they fell exceeded 1000 degrees centigrade and that the rudimentary crystalline development in the upper part of the ignimbrite at Arapuni and at other localities where these ignimbrites have been examined resulted from the material maintaining a high temperature for a considerable time. The comparative incoherence of the upper part of the deposit would be due to the smaller pressure of the overlying matter, and to the disturbing effect of gases rising from the material below.

SPECIFIC GRAVITY AND TEXTURE OF IGNIMBRITES.

It is clear that, if the pressure of the accumulating material is the cause of the so-called flow structure of the lower part of the deposit, one would expect that the specific gravity of the material that constitutes the lower part of one of these formations would be greater than the specific gravity of the rock in the higher portion. A test of this was made in connection with the formation at Arapuni itself, where the specific gravity was determined at different depths in the ignimbrite with the following results:—(1) Two feet from the base, 2·09. (2) Six feet from the base, 2·20. At eight feet, 2 16. At 14 feet, 2·00. At 20 feet, 1·95. At 30 feet, 1·81. At 45 feet, 1·57. This progressive decrease from the base upwards well illustrates the extent to which compaction took place as the result of the pressure of the overlying material. The lowest specimen is slightly vesicular, presumably because the rapid cooling did not permit of the escape of the liberated gases completely. It is clear that such a gradation of specific gravity could not develop in a lava flow.

It was found that the material of the upper surface of the ignimbrite at Arapuni was so incoherent that it could be broken with a rubber pestle in water, though it was in no way decomposed. The grading of the material treated in this way is nearly identical with that of the fine sand at the base of the rock. These have been previously stated, and are now tabulated. Lacroix's grading of the Katmai sand flow is added for comparison.

	A	B	C	
$> \frac{1}{40}$	6.60	16.34		
$\frac{1}{40} - \frac{1}{50}$	3.90	4.17		
$\frac{1}{50} - \frac{1}{60}$	2.33	3.00	> 1.65 mm = $\frac{1}{15}''$	14.57
$\frac{1}{60} - \frac{1}{80}$	3 77	2.22	0 42 mm. - 1.65 mm.	17.70
$\frac{1}{80} - \frac{1}{100}$	4 73	3.78	< 0.42 mm - $\frac{1}{40}''$	67.00
$\frac{1}{100} - \frac{1}{200}$	18 40	12.65		
$< \frac{1}{200}$	59 60	54.37		

A. Grading of material at the base of the arapunite (Arapuni).
B. Grading of material near the surface of arapunite (Arapuni)
C. Grading of Katmai sand flow (Lacroix, 1930, p. 465).

The similarity of A and B is close enough to indicate that the deposition of the material took place so rapidly that no sorting took place. The high proportion of B coarser than 1/40″ is probably due to incomplete disintegration.

Differences Between Ignimbrites and Lavas.

Previously it was stated that the very general classification of these ignimbrites as volcanic lavas did not satisfy the field conditions of their occurrence in these five respects at least:—

1. Their upper surface is approximately horizontal.
2. There are no volcanic cones which can be regarded as the source of the supposed lava.
3. There is no scoria on the upper surface of these rocks.
4. The base is formed of an entirely incoherent but narrow band of fine sand, the individual grains of which are of the same nature as that of the rock itself.
5. There is a general and pronounced vertical jointing. (Plate 70.)

It is well now to consider these field characters in relation to the "fiery shower" origin that has been suggested above for these rocks.

1. It is obvious that the upper surface of a widely distributed dust shower of considerable thickness would be of an approximately level nature if the ground previously was not particularly irregular. In general, the ignimbrites themselves lie on widely distributed pumice tuffs which are often nearly horizontal. It may here be noticed that the surface of the sand flow rock at Katmai as described by Fenner was nearly level. He publishes photographs which show a gently sloping surface, and specially mentions its level nature in his description. (Fenner, 1925, p. 196.)

2. The absence of volcanic cones formed of rhyolite rocks in this plateau area in New Zealand is a striking fact. Here, again, comparison must be made with the Katmai region as described by Fenner. He particularly mentions that the sand flow material did nót issue from any of the cones, but from fissures that are now filled up by some of the material that issued from them; and that their orifices nowhere form any surface mounds or hills. In New Zealand, though the ignimbrite area is often much intersected by stream valleys and gorges, no structure that suggests a fissure through which extrusion might have taken place has yet been described. A locality where it is now thought that such a structure may be seen is eight miles north of Taumarunui. It must, however, be mentioned again that the superficial covering of pumice greatly hampers field observations. The following is Fenner's statement in regard to the sand flow at Katmai: " During the period of eruption a broad Y-shaped valley bounded by abrupt mountains opened in numerous fissures. These are believed to have been the source from which a great volume of hot pumice and fragmental glass (' the sand flow ') was poured out and forming a phase of eruption similar in some respects to the ' nuées ardentes ' or glowing clouds of the West Indian eruption of 1902." The area that was covered by this sand flow rock was approximately twenty-two miles by eight. (Fenner, 1925, p. 194.) Fig. 5 shows the flat surface of the sand flow, and Fig. 6 indurated sand flow rock.

3. Absence of scoria on the upper surface of ignimbrites. It is clear that on the surface of a sand flow rock no scoria would be formed, for the gases originally present would generally have escaped in large proportion during the very formation and eruption of the glassy shower. In addition, the glassy particles seldom if ever adhered together with sufficient completeness to prevent the free escape of gases through the spaces between them. Even if complete welding of the particles took place the process would be slow enough to allow much of the gas to escape. The absence of a scoriaceous surface is therefore a normal and necessary condition of the formation of an ignimbrite. Its surface is thus wholly different from the scoriaceous one that would certainly develop on a lava flow of rock with the chemical characters of these ignimbrites. Within New Zealand, comparison with the Auckland basaltic lava flows and with the andesitic lavas of Tongariro, Egmont, and still more with that of the obsidian of Mayor Island, shows a complete contrast. The rough, irregular, crevassed, hummocky surface of these lavas is thus completely different from the smooth surface of the ignimbrites.

4. A rock that was formed from a fiery shower would obviously not disturb or deform the surface on which it was deposited. At Arapuni, where alone the base of an ignimbrite could be studied, it was found, as stated before, that the lowest layer consisted of a fine sand composed of a few crystals of felspar and quartz mixed with a multitude of minute but free particles or shreds of volcanic glass. This would certainly be the actual condition of the material that formed the base of a deposit from a fiery cloud. The particles of glowing glass that formed the bottom of such a cloud would be

cooled to such an extent during transit that they would lose their viscosity and would not adhere together after they fell. The base of the ignimbrite has therefore the precise character that would be expected of material deposited from the base of a fiery cloud of this nature.

5. The peculiarly general and sometimes regular vertical jointing (Plate 70, fig. 1) is clearly due to the contraction during cooling of a heated rock that was completely at rest and effectively solid. The extreme viscosity of such an acid glass, and the amount of cooling that it had already undergone, would practically prevent it from developing any mass flow after it was deposited It would, however, after its deposition cool through an interval of temperature amounting to approximately 1000 degrees centigrade This implies a large amount of contraction which would best be satisfied by the development of a series of vertical joints producing a roughly hexagonal prismatic character A noticeable point is the difference in the diameter of the vertical rock columns in various deposits of the ignimbrites At Arapuni they are about one foot in diameter; at Ngutuwera their diameter is about three or four feet; at Hinuera they are as much as eight feet in diameter.

This difference in the diameter of the columns may well be due to the initial temperature of the ignimbrite as it was deposited in different localities—the higher the temperature, the more closely the vertical joints would be spaced. There is internal evidence in favour of this. At Arapuni, where the columns are of narrow diameter, the glassy particles of the ignimbrites were of such a high temperature that they fused together almost rigidly and show well-developed parallel arrangement or so-called "flow structure." At Ngutuwera the columns are far larger, and here no parallel arrangement can be seen. At Hinuera, where the dimensions of the columns are very great, the glass particles have much of the characteristic form of the particles in ordinary tuffs—in other words, they were nearly solid when they reached the ground.

The question obviously arises here as to the extent to which welding of the particles of glass might take place, under the most favourable conditions, after they had fallen, and to what extent reconstituted glassy lavas might be formed. The possibility of the crystallisation of various minerals of igneous rocks in such material also arises. Further reference to both of these questions will be made subsequently.

Sollas appears to have had a suspicion that the material of some of the Hauraki tuffs reached the ground in a viscous state, as the following extracts show (Sollas, l.c., vol. 2, p. 66): "The slice is seen to be composed of contorted flow shreds of the form supposed to be characteristic of tuffs, the interstices filled with darker, more granular glass. The tuff-like bodies contain globulites and spirally curved thread-like crystallites which would be called trichytes were they not transparent." "There can be no manner of doubt about the original glassy character of the shreds. Their crystalline character at present is obvious, and thus we appear to have definite

evidence of secondary devitrification. The only escape from this inference lies in the possibility that the contorted threads were not wholly solid, but simply viscous, after they acquired their form." "Rhyolite with plagioclase showing contorted flow lines."

THE TEMPERATURE OF IGNIMBRITE MATERIAL.

The following considerations will give some indication of the temperature of the material of the ignimbrites when deposited.—

(1) Quartz crystals are found in practically all of these rocks. In all ordinary instances these crystals are phenocrysts that have been formed before eruption.

(2) Tridymite has often been formed in the later stages of cooling after eruption.

(3) The glass particles were generally in a viscous state.

(4) In some cases the glass was drawn into threads.

(5) The glass sometimes contains small crystallites and globulites that were formed after eruption.

(6) Spherulitic structures of several types have often been developed in the glass after it fell.

(7) Samples of these rocks raised to a white heat in a blacksmith's furnace fused to a highly viscous material. However, samples heated to a temperature of 1000 degrees centigrade by Mr E. T. Seelye were unaltered.

The temperatures indicated by these observations are as follows:

(1) Not more under surface conditions than	870° C.
(2) Not less than	870° C.
(3) In andesitic material 938° C., in this material probably	1100° C.
(4) In this rock probably not less than	1200° C.
(5) No definite indication as minerals could not be identified.	
(6) This could take place at any temperature above	460° C.
(7) The rock fuses to a highly viscous glass at ..	1200° C.

On the other hand, no crystobalite was seen, which implies that the temperature was less than 1470° C.

The low temperature that is suggested by (1) may possibly be due to different molecular conditions which permitted the crystallisation of silica into quartz at high pressures in spite of high temperatures; or, conversely, that union of gaseous constituents developed high temperatures when pressure fell. At any rate, the abundance

of quartz crystals in association with this acid glass cannot be denied; the grains are large and rounded, and were certainly formed before eruption.

Lacroix maintains that at Mount Pelée the quartz crystals were formed after the consolidation of the rock. The corroded and cracked nature of the quartz precludes this explanation in regard to the ignimbrites that are here described. (Lacroix, 1908, p. 52.)

Chemical Composition.

Few analyses have been made of these ignimbrites. Morgan, however, quotes five of them. (Morgan, 1924, p. 70.) Two of them are given here. Henderson gives some others (Henderson, 1923, p. 57); Grange also gives one (Grange, 1927, p. 40). Some analyses of the Mayor Island comendite are given for comparison. Mr F. T. Seelye has kindly given me analysis K.

	A		C	D	E	F	G	H	K
SiO_2	73.08	72.89	72.40	75.46	70.10	67.83	72.30	69.61	72.82
Al_2O_3	13.50	12.83	10.00	11.27	13.76	14.68	12.50	15.53	13.53
Fe_2O_3	2.60	1.04	6.17	1.17	2.64	4.79	2.12	1.49	2.06
FeO	0.13	0.38	0.93	2.05	0.79		0.47	0.83	
MgO	0.15	0.06	none	0.27	0.17	0.69	0.10	0.32	0.06
CaO	1.07	1.25	0.22	0.53	1.33	2.81	1.35	2.27	1.66
K_2O	3.19	3.92	4.64	4.88	3.08	2.90	3.58	2.76	3.86
Na_2O	3.95	2.81	5.43	3.45	3.42	3.46	3.25	3.86	2.93
$H_2O - 105°$	1.33	0.96	0.29	0.28	0.88	0.66	0.46	1.13	0.71
$H_2O + 105°$		3.46		0.07	3.74	1.87	3.54	1.86	1.45
TiO_2	0.62	0.12		0.05	0.26	0.43	0.12	0.37	0.23
P_2O_5	tr	0.03	0.02				0.31	0.06	0.04
BaO	0.06	0.09						0.08	
								MnO	0.02
	99.68	99.83	100.00	99.48	100.17	100.12	100.20	100.17	99.37

A. Rhyolite (lithoidal) 100 feet down No. 1 shaft, Grand Junction mine, Waihi. Lower down on p. 70 this rock is called tridymite rhyolite.

B. Rhyolitic tuff (wilsonite) from quarry, Waitekauri stream crossing the old Waihi-Paeroa road.

C. Obsidian, Mayor Island. Washington, N.S.G.S. Prof. Paper, No. 99.

D. Pantelleritic rhyolite, Mayor Island. von Wolff, 1904.

E. Rhyolite breccia, quarry N.W. Otorohanga Railway Station. (Henderson and Ongley, 1923, p. 57.)

F. Rhyolite breccia, Arapuni Gorge. (Henderson, 1923, p. 57.)

G. Rhyolite breccia, near Waikino. (Henderson, 1923, p. 57.)

H. Rhyolite tuff, Lower Pleistocene. (Grange, 1927, p. 40.)

K. Tridymite rhyolite, opposite gasworks, Waihi. Mr F. T. Seelye.

Sample A from Waihi is substantially the same in composition as the other samples which have been obtained from localities far apart. All the analyses show that the rock is a rhyolite in composition, though the lime content is rather higher than is usually the case in such rocks. The alkalies, too, have rather different amounts, but in each case the sum has nearly the same value in the other rocks, with the exception of the alkaline types (comendites) from Mayor Island.

Sample G is the typical wilsonite. There is nothing in its composition that distinguishes it from the other types of these tufaceous rocks.

Analyses C and D of the pantelleritic or comendite rocks of Mayor Island are quoted for comparison only. Lava flows of this type are well developed, and have a thick surface of obsidian, while the interior parts of the lavas are of a stony nature. This feature as well as the roughness of surface and inclination of the formation at once distinguishes these lavas of Mayor Island from the ignimbrites which have been described above.

CHANGES IN THE GLASS OF IGNIMBRITES AFTER THEIR DEPOSITION.

Hitherto the ignimbrites have been described as composed of relatively large crystals of felspar and quartz embedded in a maze of minute glass shreds. It is, however, in a few places only that the glass shreds still retain their vitreous characteristics. Actually, so far as the very numerous specimens that have been examined are concerned, it is only in the wilsonite from Owharoa, and in that from Waikino, and in the lower layers at Putaruru, and in the lower ten feet on the fine grained rock at Arapuni, as well as that from the lower part of the deposit at Hinuera that this vitreous material is still dominant. In practically all of the other samples the glassy nature has been lost; though the form of the originally glass particles has been retained, or is still visible in a maze of other structures. The variety of these structures is very great, and their development is often so pronounced as sometimes, at first sight, to conceal the structural features of glass shreds which reveal the ignimbrite origin.

It is thought that the temperature of the ignimbrite material was so high, even after deposition, that some crystallisation took place within the glass fragments; sometimes, indeed, to such an extent as to dominate the rock structures.

Pectinate Structure.

Such changes are seen in their most rudimentary development in the rock of the Paeroa ranges, close to the crossing of the Waikato River, on the road from Rotorua to Taupo; and to some extent also in the lower part of the rock at Hinuera. This most minute change is the development of very slender colourless needles at right angles to the surface of the glass shreds and extending inwards from it. A resemblance between these needles and the teeth of a comb suggests the use of the term pectinate which is here applied to them. This pectinate structure in the instances that have been mentioned has been developed without any simultaneous alteration of the rest of the material of the glass shreds. The alteration usually proceeds further than this, and in the majority of instances it has been complete, and no glassy residue remains. The sharpness of the teeth in the pectinate structure usually becomes less pronounced as the structure develops, and whilst this change takes place in the margin

of a glass shred, the central portion also changes, and soon becomes an indefinite mass of feebly birefringent particles which are thought to be tablets of tridymite. This development has proceeded to such an extent in many of the rocks as to effect the entire obliteration of the glass. This is the case in the upper part of the Arapuni occurrence, as well as that of Maraetai 5, and along the course of the Mangakino River, and at Motutere on Lake Taupo. In other localities, notably at Puketiti west of Te Kuiti, at Tarawera on the Napier-Taupo road, and near Maungatautari, the whole local development of the rock appears to be changed in this way and without any further advance.

It is to be noted, however, that this structural alteration has been effected without any change in the form of the shreds originally glass, which in the instances mentioned still retain their irregularly disposed arrangement. At times it almost seems as though this alteration had taken place before the glass particles had reached the ground. The pectinate development often continues far, even in those parts of the rock that were subject to such pressure from overlying material that the glass shreds have a parallel arrangement and " flow structure " becomes pronounced.

In other localities the felspar fibres become far stouter, the core of tridymite becomes distinct, and a so-called axiolitic structure is developed. Within this region such a structure is dominant in many places. In the large occurrence near Ongaruhe, notably at Waimiha, it is found consistently throughout the whole mass of the ignimbrite, which here is from 60 to 100 feet in thickness. (Plate 64, fig. 1.)

Radial or Spherulitic Structure.

There appears to be a tendency for some of the pectinate structures to grow at the expense of others, and the felspar needles or fibres may extend from their own glass shred across the finer dusty substance that intervenes between the glass shreds and join up with those formed in another. There seems to be a general tendency to round the structures off, and negative radial structures or spherulites result. A few of these spherulitic or radial areas are to be found in most of the rocks in which this general pectinate character is dominant. This structure is quite distinct in patches of the " indurated sand flow rock " from Katmai given to me by Dr Fenner. The radial structures, however, are at first markedly irregular, though a rock of this kind would normally be called a spherulitic rhyolite. Even when the radial structure is well developed the boundaries and many of the features of the original glass particles can still be distinctly seen.

In some rocks that at first seem to be typical spherulitic rhyolites, as for instance in the quarry on Mount Ngongotaha on the road to the summit, distinct dusty lines cross the fibres of the well-formed spherulites, and comparison of these with the structures in the lower rocks at Motutere suggests that even this spherulitic rock at Ngongotaha may have an ignimbrite origin. (Plate 68, fig. 1.)

DEVELOPMENT OF PECTINATE AND RADIAL STRUCTURES IN PINK WILSONITE.

The pink wilsonite from Putaruru shows in the most striking manner the development of radial structures. As this change is at first associated with the large fragments of glass in the rock, a separate description is necessary. The large glass fragments, which are sometimes as much as 20 centimetres in length, are narrowly lenticular, a form due to their viscosity when deposited, and to the vertical pressure of overlying matter. These glass fragments contain numbers of capillary gas pores which lie in the direction of the greatest diameter of the glass lenticle. (Plate 66, fig. 2.) In specimens of rock from the base of the deposit these lenticles have no crystalline structure, but are pure glass, except for a few larger crystals of quartz and felspar which belong to an earlier period, and occur generally in all of these rocks. The rest of this wilsonite is composed of irregularly arranged shreds of brown glass, with others of smaller size almost colourless, and a good deal of dusty matter between them. A few feet above the base of this wilsonite there is a complete change in the detailed structure. The dark lenticles are still quite distinct in hand specimens and in section; but in all of them innumerable felspar fibres have been formed with their axes at right angles to the capillary pores and directed into the glass like the teeth of a comb. A number of axiolites have thus arisen within the glass lenticles each with a central line of tridymite more or less distinct. (Plate 67, fig. 1.) Sometimes the felspar fibres extend across two or three of the capillary gas pores, and sometimes rounded radial groups of spherulites have been formed. (Plate 67, fig. 2.) In some examples the lenticular fragments have formed spongy masses of spherulites. (Plate 68, fig. 2.)

The rock has thus become a distinct pectinate type, with here and there some radial development. In hand specimens occasionally spherulites large enough to be distinctly seen with the naked eye are clearly visible when one of the lenticles has been broken across. Occasionally some of these lenticles become vesicular, and even in hand specimens projecting spherulites can be easily seen. This structure is maintained to the top of the pink wilsonite, though the texture becomes rather less compact and the rock softer. It is at once evident that crystallisation begins sooner and is more active in the larger lenticles of glass than elsewhere in the rock.

DEVELOPMENT OF STRUCTURES AT MARAETAI 5. (Plate 70, Figs. 1, 2.)

At Maraetai 5 of the Perpetual Forests' estate the Waikato River flows in a gorge which here is 350 feet deep. This can be well seen from the trig station 1003, which is approximately 1258 feet above the sea level. From the level of the trig to the bottom of the gorge the rock is ignimbrite with distinct columnar structure, and no discontinuity could be seen in it of such a nature as to suggest that there was more than one period of deposition. The rock at 350

feet above the water level is of a pink colour, and is not very compact, with a specific gravity of 1 91 when saturated with water. At the 200 feet level the rock is less pink, but more compact, and its specific gravity has risen to 2·03. At the water level the pink colour has been lost, and the rock is now compact, with specific gravity of 2 26. These three rocks have porosity of 28 4, 25 9, and 13 4 respectively.

The structure of the sample from the 350 feet level is poorly pectinate, but the component particles have all of that fluffy, irregular arrangement that is found in characteristic tuffs. (Plate 63, fig. 2.) This material, when it was deposited, contained relatively large rock or glass fragments. These have undergone considerable alteration. In hand specimens they are soft and pulverulent. In section they consist of distinct and separated spherulites with much tridymite. In a few instances the pectinate structure has developed distinctly parallel to the capillary pores. It is interesting and important to note that the aspect of this rock in hand specimens is closely similar to that of the "indurated sand flow rock" of Katmai; for a sample of which I am deeply indebted to Dr Fenner The resemblance between the two rocks in hand specimens is maintained in micro preparations, even to the peculiar elementary pectinate structure and the radial or spherulitic structure of some of the patches, which are thought to have been glass originally. This seems to support the probability of a similarity of origin in the most definite manner. In itself it demonstrates that this rock of Maraetai 5, at least, has been formed from the material of a fiery shower.

At a level 150 feet lower, that is, about 200 feet above the river, the tuffaceous character is still dominant in the rock; but the pectinate character is more developed, and the original larger glass fragments are less spongy and show traces of capillary pores more clearly. Parallel arrangement of the shreds or "flow structure" is shown but slightly.

At the water level the pectinate structure is very distinct, with a radial tendency, and the rock would normally be called an axiolitic or even a spherulitic rhyolite. The bending of the pectinate structures round the crystal edges and angles is characteristic, giving a vivid impression of "flow structure." The original large glass lenticles are now quite dense and are formed of spherulites in close contact, while the original capillary pore effect is not visible. Throughout the rock a radial development is now frequent; but usually the form and arrangement of the original glass shreds can be seen in the spherulites even when they are well formed and circular in section. (Plate 64, fig. 2.)

Development of Structures at Te Toki Point, Lake Taupo.

Near Motutere Point, on the east shore of Lake Taupo, at the spot where the road from Tokaanu to Tapuaeharuru passes round the rocky bluff, the development of pectinate, and radial, as well as vitreous structure is well seen. The rocky bluff is approximately

250 feet high. Fourteen specimens were taken from this cliff for examination. As far as possible, the spots from which these were taken were evenly spaced from the top to the bottom of the cliff.

The top sample, which is a soft rock, has a typical tufaceous nature. The glass shreds of which it is composed have a feathery arrangement and a rudimentary pectinate structure. There are a few patches of small size, some of which have a spherulitic nature. Each sample from a spot successively lower in the outcrop shows a higher development of pectinate structure, while the shreds are more compactly arranged. At No. 7, which is approximately 120 feet from the surface, the pectinate structure has become dominant and the feathery character has become almost lost, for the shreds have taken up a roughly parallel arrangement and already can be seen to bend round the angles of the included crystals, and thus give the appearance of flow structure.

In the samples from still lower levels the pectinate structure becomes stronger, and more fully developed. The parallel fibres of felspar are longer and more distinct, and occasionally the fibres in two adjacent glass shreds unite, while the terminations of the shreds have a tendency to round off, and thus develop an irregular spherulite which is still of the transparent or negative type. At the same time, especially from specimens near the base, the streaming appearance of the pectinate representatives of the original glass shreds now presents an impression of typical and pronounced flow structure. Examination of this series of preparations gives no room for doubt that the whole outcrop is a rock of ignimbrite origin, in which the pressure of overlying material has developed flow structure in the lower portions, while the temperature of the material, after it fell, was sufficiently high to allow of development of axiolitic and spherulitic structures. (Plate 65, fig. 1.) The lowest rock of all, which is now unfortunately hidden by detritus deposited from road-making operations, illustrates still other changes that the ignimbrite material underwent after its fall.

One often finds in this lowest rock at Te Toki that there are irregular patches of clear, colourless glass, sometimes of considerable size. One of these measures 1·2 cm. by 0·4 cm. (Plate 65, fig. 2; plate 66, fig. 1.) These patches often have a ramified shape, and the branches penetrate far into and among the original glass shreds. These patches of colourless glass have irregular and ragged borders. Dusty matter contained in them sometimes follows the lines of those brown glass shreds across which the patch extends. Near its border a few small microlites may occur similar to those in the fine dusty matter between the glass shreds. It is impossible to resist the conclusion that this colourless glass has resulted from the fusion or welding in place of original glass shreds of the ignimbrite. In this colourless glass bubbles of gas are not infrequent. In almost all cases they have a perfect rounded form, though occasionally they are slightly oval in shape. This shows clearly that no movement took place in the colourless glass after it had been formed. The dusty

lines are not flow lines in the glass, but are merely inherited structures from the ignimbrite. It is interesting to note that, in the colourless secondary glass, strings of margarites are sometimes found, and occasionally they develop into the curved radiating groups which form such a picturesque micro-feature of the Aratiatia rocks. Spherulitic structure with the dark brown positive spherulites has developed more strongly and regularly in this colourless secondary glass than in the glass shredded ignimbrite material; but lithophyses are not so common Some, however, were observed with crystals of tridymite projecting from their sides. The cause of the fusion of patches of the rock cannot be certainly stated. It is, of course, probable that the temperature was somewhat uneven at the moment of deposition. Gaseous reactions too probably took place to a considerable extent, and may have caused local increase of temperature.

These observations and descriptions are, of course, opposed to the statements of Weinschenk and Clark (1912, p. 333, fig. 235): "Rock glasses often present the appearance of decided flow structure. In these glasses various coloured bands, mixed with each other in multifarious ways, form the principal constituent. In other cases they flow round the large crystals that have separated out, so that it appears that the different parts were not miscible with one another even in the liquid condition."

Seeing, however, that clear glass has been formed in this Motutere rock from ignimbrite material after it fell, the question arises as to whether the glassy rocks that contain spherulites have also been formed in this manner from incandescent showers. It is, of course, probable that a far more glassy structure than that observed at Te Toki might be developed.

The field geology of these acid volcanic rocks in this district is of such a uniform nature that it suggests a common method of eruption. Each of the separate areas, however, requires detailed examination before definite statement can be made. At present it can only be said that the structure of the rock of the isolated hill Kaimanawa, which is a granular—not a solid obsidian rather suggests such an origin. The trichites, too, in this rock are of precisely the same nature as those formed in the clear welded glass of Motutere. Again, the well-known rock of the Hemo Gorge near Rotorua with its numerous spherulites enclosed in a somewhat granular glass has a structure which in some respects closely resembles that of the colourless portion of the rock at Motutere.

Compaction of Ignimbrite at Te Toki.

In order that this apparently distinct evidence of compaction in the structure of the rock at different levels should be tested, the specific gravity of the different samples from top to bottom of the deposit at Motutere was determined with the following results. The samples were soaked with water before estimation of the S.G.

	Porosity.	Specific Gravity. When soaked.	Specific Gravity. Calculated dry.
1	28.6	1.96	1.67
2	25.2	2.09	1.83
3	23.4	2.11	1.87
4	22.0	2.15	1.93
5	20.0	2.17	1.97
6	19.8	2.16	1.96
7	23.1	2.13	1.90
8	18.4	2.19	2.01
9	9.2	2.38	2.28
10	10.7	2.24	2.13
11	9.9	2.36	2.26
12	8.4	2.39	2.31
13	8.0	2.40	2.32
14	3.4	2.41	2.37

This table gives remarkable evidence of the compaction of the rock as the distance from the surface increases. The two apparent exceptions in no way detract from this conclusion. The specimens had been collected, without any intention to use them for this purpose, and both No. 5 and No. 9 had a considerable portion of the weathered surface adhering to them. This external surface always has a considerable amount of secondary silica deposited in the pores. This, of course, decreases the porosity and increases the specific gravity. The actual amount of this effect was estimated in a sample from the locality Maraetai 5. In this instance the specific gravity of the exterior surface was 2·04 with porosity 7·96, while the inner portion had porosity 12·01 and specific gravity 1·83.

It may perhaps be said that consideration of the above observations shows that the temperature of the ignimbrite when it first reaches the ground may be as high as the fusion point of this acid glass and may remain at this temperature long enough to allow of the formation of positive spherulites. In other portions under less pressure negative spherulites may be formed in such numbers as to develop a structure that cannot be distinguished from that of a typical spherulitic rhyolite. Mr E. T. Seelye, of the Dominion Laboratory, was good enough to submit some samples of several of these rocks to a temperature of 1200 deg. C., but microscopic examination of these specimens failed to discover any difference in structure, even when the treatment was continued for six hours. Many spherulitic rhyolites in the Rotorua district have definite lines extending through the spherulites. Examination of some of those observed suggests that the lines mark the direction of original glass shreds.

That spherulites may form in the glass of rhyolites as distinct from material in the state of fusion was recognised by Harker. " When they " (spherulites) " are developed in a glassy or devitrified matrix the flow lines are seen to pass uninterruptedly through

the spherulites, and, indeed, the latter may sometimes be seen to have formed subsequently to brecciation of the rock. In such a case the matrix was a glass rather than a liquid when the spherulites crystallised." (Harker, 1909, p. 275.)

Experimental Evidence in Regard to Crystallisation in Acid Materials.

Until quite recently there has been little or no information in regard to the conditions under which crystallisation might take place in an acid magma, and of the actual temperature required for fusion at the probable depth from which such a magma might be derived. Recently experiments which are of great importance in this connection have been made by Roy W. Goranson. (Goranson, 1932, p. 227.) These experiments have involved pressures extending to 1500 bars, and in some cases the temperature reached 1000 degrees centigrade. These conditions were in some cases maintained for 160 hours. Finely ground granite powder was used in most of the experiments, but in some instances finely ground granite glass was used, which had been previously prepared by fusion of samples of the same granite. Various quantities of water were used with the granite in the different experiments.

Goranson found that at 1000 deg. C. and 960 bars no glass was formed, though with 15 per cent. of water 80 per cent. of the rock became glass. Even at 704 deg. and 960 bars 70 per cent. of the material was changed into glass when 4·4 per cent. of water was present. In this case the grains that remained unfused were all quartz. In other experiments the quartz grains that remained were highly corroded. Even at 600 degrees in 460 hours a small amount of glass was formed. On the other hand, granite glass at 600 degrees and 385 bars with 2·6 per cent. of water became a mass of birefringent grains. It is particularly interesting to note that silica glass treated for 3 hours at 900 degrees and 1000 bars crystallised directly to quartz.

As a result of his experiments, Goranson concluded that a granite magma with 1 per cent. of water at a depth of 10 kil. will begin to crystallise at 1025 C. When the temperature reaches 700 C. 85 per cent. of the original matter will have crystallised. If such a magma were at a depth of 4 kil. crystallisation would take place while the temperature fell from 1025 to 950 C. About 65 per cent. will then have crystallised, and any further crystallisation will be accompanied by an ebullition of water. A similar result would be effected if the magma at 10 kil. contained 3 per cent. of water, and was cooled to 700 C. Fifty per cent. would then have crystallised and ebullition would take place. These results are particularly illuminating in connection with the acid rocks that are now being considered. Not only would crystals be formed including those of quartz; but at the lower temperatures the quartz crystals, that might have formed, could be much corroded. In addition to

this, the residual glass would be highly charged with water throughout its mass. If pressure were reduced, as might well be the case, it would seem that the natural result would be the shattering of the highly viscous magma. This condition is of the precise nature required for the production of an ignimbrite as here defined.

Goranson's experiments with granite glass show that crystallisation may take place in this acid material even at a low temperature, though he certainly employed a pressure far greater than that which would operate in connection with an ignimbrite, the materials of which after eruption would have been subject to pressures of a few atmospheres only.

Here, however, the facts that have been recorded by Penrose in regard to the crystallisation that takes place on the internal surface of adjacent glass sheets in an annealing oven are of special interest. He describes axiolitic and spherulitic crystallisation in artificial glass. (Penrose, p. 112, pl. 1.) A further note on p. 425 is based on a letter from R. L. Frink, a technical engineer who has made a special study of the glass industry. He points out that the axiolitic structure can be produced at will in the flattening ovens by laying sheets of glass one upon the other and submitting them to the action of heat for varying intervals of time. The longer the time, the more opaque the glass will become. This observation of physical processes at glass works is clearly of a similar character as that supposed in this paper as the cause of the pectinate structure, which is so often observed in the earlier stages of the crystallisation process, in the series of glass shreds of which ignimbrites are mainly made up. This important statement of Penrose was overlooked until long after similar conclusions had been reached from a study of these ignimbrites. Penrose suggests that the layer of air between the glass plates aids in the process of crystallisation. It is, however, probable that in an ignimbrite derived from a nuée ardente all the gases present would be of magmatic derivation and more active than air in virtue of their nature and their origin.

POSSIBLE RELATIONS BETWEEN SPHERULITIC RHYOLITES AND IGNIMBRITES.

The descriptions and statements that have been given above render it clear that rocks which ordinarily would be classed as axiolitic, spherulitic, and flow rhyolites, as well as pitchstones, may in some cases at least have an ignimbrite origin. The area over which rocks of this nature occur in the North Island of New Zealand is large, and their thickness in portions of it at least is surprising. Obviously the question arises as to whether the rocks of some of the areas of spherulitic rhyolite, of relatively coarse texture, in which no remnant of ignimbrite origin is evident, have actually been formed in this way. The sample of spherulitic rhyolite from the quarry on the south-west side of Ngongotaha shows distinct remnants of original structure which suggest an ignimbrite history. (Plate 68, fig. 1.)

The frequent occurrence of spherulitic rhyolite rocks in beds which are almost horizontal, without a scoriaceous surface, without obsidian selvages, with a columnar structure, and with a relatively crumbly nature show at least that such huge masses as that at Horohoro, eight miles in length and from two to six hundred feet in thickness, if of lava origin, must have had an extreme fluidity, and must have come to complete rest before they solidified. It is extremely difficult to conceive that such conditions could have actually occurred.

Mr E. T. Seelye has kindly submitted some of the New Zealand volcanic glasses to various temperatures with the following results.

Samples of glass or obsidian from the upper part of comendite lava flows at Mayor Island, where there is a selvage of obsidian sometimes four feet thick on the upper surface and about the same thickness on the lower surface. Other samples were from Rotorua and from Waihi. In both of these cases, however, the samples were taken from distributed boulders.

At a temperature of 600–660 C. after four days the samples from Mayor Island became finely vesicular and puffed out. The Waihi and Rotorua samples, however, were not affected. At a temperature of 900 degrees for three days the bubbles had escaped from the Mayor Island samples, but a strong vesicular structure had now developed in the samples from Rotorua and Waihi. The surface tension and viscosity apparently even at this temperature had been so great as to prevent the gases from escaping. At a temperature of 1000 to 1020 C. a very vesicular pumice was developed from the Waihi specimen, while the Mayor Island samples simply fused and the Rotorua samples were not tested.

The Mayor Island obsidian thus fuses completely with elimination of bubbles at 900 degrees, though it retains bubbles and becomes pumiceous at 600–660 degrees. True lavas of this rock have definitely flowed, and they have a rough, irregular surface with an obsidian coating above and below with a body of regularly crystalline material.

The obsidians from Waihi and Rotorua retain abundant bubbles at 900, and in the former case at 1000 degrees also, in such amount as to be regularly pumiceous, and they show no indication at this higher temperature of the pronounced flow of the Mayor Island obsidian at 900 degrees.

It would seem, then, that if Horohoro was formed of lava rock this huge mass of material must have flowed through its present extent, though certainly extremely viscous and very slow moving, without its temperature in its upper or lower portions falling below 1200 degrees at the very lowest.

Such conditions seem to be beyond the imagination and to transcend the possibilities. On the other hand, there are masses of rock of ignimbrite origin with dimensions of a similar order. At Maraetai 5, for example, as a centre, there are immense masses distinctly of ignimbrite origin: though these have a less complete spherulitic structure than the Horohoro mass, but at present the

latter is not completely known in detail. Similar remarks apply to such large but isolated masses of spherulitic rhyolite as that at Tumunui, on the Taupo-Rotorua road, and perhaps even at Arotiatia.

It is clear, however, that much more field work and very much more petrographic work is required before any assertion can be ventured in regard to the origin of these rocks; though the facts that have been brought forward in this paper appear to the author to establish a strong possibility that they may have an ignimbrite origin.

Other Areas of Rhyolitic Rock.

One is tempted here to make comparisons with the rocks and conditions in other areas in which rhyolitic rocks occur. The author, however, has little personal knowledge of these.

Within New Zealand rhyolitic rocks occur over a large area in the South Island, with the well-known Mount Somers as a centre. Here, however, the rhyolites are older than the Upper Cretaceous. Professor Speight, who has devoted particular attention to this region, has remarked on the wide slightly inclined beds of rhyolites found there and of the occurrence of pitchstones at the base, of a nature that is closely similar to the glassy facies at the base of the Motutere outcrop.

At Brisbane the tuffs have presented difficulties because on the one hand of the evidence of high temperature; and on the other the columnar form with a certain flow structure have been thought by some to indicate that the formation was an actual rhyolite lava. Here, again, the rocks have a wide extension and are nearly horizontal.

Rhyolites have a wide occurrence in the Yellowstone Park of the United States of America. The rocks of this area have been described at some length by Professor Iddings. (Iddings, 1889.) It is evident from a mere inspection of Plates 50, 51, that Iddings encountered many rocks that are almost identical in their features with those called ignimbrites in this paper. He seems to have experienced great difficulty in accounting for their various structures.

On page 403 he states: "The colourless glasses free from microlites are in almost every instance highly pumiceous, so that the glass solidified in thin rods or films. . . . In some instances it is evident from the confusedly twisted and curved arrangement of the glass fibres and films that the inflated glass mass settled back upon itself or collapsed after the escape of much of the gas. . . . Hence, in a moving stream of rhyolitic lava, portions which have been inflated to pumice may be forced whilst yet plastic into more compact masses by movement of the lava, and they may be expected to exhibit some indication of their former pumiceous condition. When we remember the former enormous extent of many of the streams of rhyolite in this region we may easily imagine the formation of pumice over the surface of an intensely heated area of lava thus permitting of its subsequent welding."

P. 465: "In numerous cases a pumiceous character is entirely wanting. The mass is a compact glass, but it consists of irregularly shaped shreds and patches of different colour. These twist and curve round one another and appear like a perfectly welded mass of strips and ribbons and irregular fragments of variously coloured glass. In some cases their shape closely resembles that of fragments of pumice pressed closely together and welded."

Iddings again deals with this subject in his volume on Igneous Rocks. (Iddings, 1909, p. 331.) "In case the collapse has not been complete there may be porous spaces, and if the lava has flowed enough to draw out the welded glass the structure appears as in fig. 21. In a completely welded pumice that has been long drawn out the structure appears as in fig. 22. In this rock spherulitic crystallisation has arranged itself along the axes of the welded threads—a structure known as axiolitic, already described in connection with spherulitic crystallisation." The rocks seem very similar to those in New Zealand, and the explanation as collapsed pumice is quite unsatisfactory.

The rhyolites of the Lake District of England appear to present some problems similar to those discussed here. J. F. N. Green, for instance, says: "The frequent exposure of a thin bed of bedded ash below this rock points to virtual horizontality. . . . These examples merely illustrate the general impression of horizontality and wide extension formed when traversing the lava outcrops. . . . Nothing in the Lake District is more noticeable, or at first sight more surprising, than the great proportion which weather with a brecciated structure sometimes invisible on a freshly broken surface, but detectable under the microscope by variations in size of the little felspar laths and in the colour of the glass.

"Further for some reason vesicular structure is very rare in Lake Country rhyolites so that the increase of density with solidification has full effect. This may account for the fact that included fragments usually rounded or lenticular are found throughout nearly all the rhyolites. They are often drawn out and bent, following flow lines, and there is a complete gradation from rhyolites with rounded or subangular enclosures, having a disquieting resemblance to a tuff when weathered, to a well-banded rock." (Green, 1919, p. 163.)

These quotations indicate that very general but perplexing problems similar to those met with in the Rotorua–Taupo region are encountered in other districts where rhyolite rocks are found. It would seem that some, if not all, of these difficulties would be resolved if an ignimbrite origin could be assigned to them.

Ignimbrites as Building Stones.

It has been stated that ignimbrites are almost entirely composed of crystals of felspar and quartz embedded in a multitude of shreds of glass. Each of these substances is, of course, immune from the destructive effect of weathering within the lapse of a historical

period. There can be no question as to the lasting qualities of a rock formed of these substances when exposed to atmospheric conditions. In ordinary tuffs the particles are merely pressed together or are cemented together by such a substance as carbonate of lime. Such a cementing substance is subject to gradual solution, and the rock which depends on it for solidity will crumble.

The fact that the glass particles of an ignimbrite are welded together confers on the aggregate a resisting power immensely greater than that of a cemented tuff or sandstone. In the field evidence of this resistance is abundantly shown on the exposed outcrops; for there is no disintegration and no flaking on them. Actually, the exposed surface has a hard crust due to the deposition of silica which is presumed to have been derived with extreme slowness from the finest elements of the ignimbrite.

The resistance to distintegration is well shown by the behaviour of the rocks when treated with acid. When boiled in hydrochloric and in sulphuric acids each of the five types that have been tested has been found to harden to a decided extent. This is the case after repeated boiling in acids and drying of certain samples over a period of four years.

Ignimbrites from Hinuera and Ngutuwera have been used in small quantities in buildings at Auckland and Litchfield as much as forty years ago, and to-day the stone shows no sign of deterioration. This is the case where the stone is in contact with wet ground, as well as fresh water and salt water. Ignimbrites from various outcrops have been largely used in railway works for fifty years, especially for platform curbings, lining of culverts, and bridge approaches, and in no case has any deterioration been observed. The stone has considerable porosity and absorption in common with all relatively soft rocks. In New Zealand climates this cannot be regarded as an important matter. It is only in regions where extremely sharp frosts immediately succeed heavy rainfall of some days' duration, which completely saturates the stone, that any serious effect would result. There are no inhabited localities in New Zealand where such an association of conditions is experienced. The columnar jointing causes the stone to break out easily in a quarry, and it is so soft that it is readily squared without undue expenditure. It is practically a free stone, and can be worked with equal ease in all planes. The great variety of texture and tone will give opportunity to develop almost any architectural effect that is desired.

CLASSIFICATION OF IGNIMBRITES.

The following classification of ignimbrite rocks is suggested:—

Ignimbrites.—Igneous rocks of acid or perhaps intermediate composition which have been formed from material that has been ejected from orifices in the form of a multitude of highly incandescent particles which were mainly of a minute size.

It has, however, to be borne in mind that in any single deposit formed from such material many different types of structure or phases may be developed. These differences in structure are thought to be due to the pressure of overlying material and to the distance from a cooling surface; in other words, to the relative time during which a high temperature was maintained. It is not possible, therefore, to name any one structure as characteristic of any one deposit of ignimbrite.

Since structure fails, it has been found advisable to use texture as the basis of the main divisions of ignimbrites. Subdivisions or phases, however, are based upon structure. Ignimbrites are usually thick rock masses with well-developed vertical prismatic jointing.

A. Pulverulites.—Essentially fine grained rocks. Composed of fine dust like shreds of glass surrounding crystal grains of quartz, felspar, and some hypersthene, hornblende, or biotite.

B. Lenticulites.—These rocks contain conspicuous lenses usually of dark material often drawn out. These are embedded in a matrix of fine glassy shreds amongst which are some crystals more or less rounded in outline.

C. Lapidites.—Pieces of rock not drawn out or lenticular are embedded in fine material which is composed mainly of shreds of glass.

Each of these classes of ignimbrites may have the following phases:—

1 Vitreous.—Apart from crystals all the fine matter and lenses if present are formed of glass.

2. Radial.—Crystallisation in the form of radial groups has developed quite independently of the boundaries of the original particles of glass.

3. Pectinate.—A comb-like development of extremely fine felspar needles with their axes at right angles to the margins of glass shreds. There is often fine granular matter along the middle line. In the more highly developed examples this fine granular matter is found to be tridymite.

4. Plumose phase.—The minute particles are lightly arranged and are in no way deformed. Their arrangement suggests downy matter.

A. Pulverulites.—Thirty to as much as four hundred feet thick. Examples at Arapuni, Ngutuwera, Toki Point (Lake Taupo), Waihi.

1. Vitreous phase.—This is usually restricted to a thickness of a few feet near the base of the deposit. The incandescent particles in most cases were of such a high temperature when deposited that they were viscous and the pressure of overlying matter bent them round the angles of crystals and thus gave rise to the appearance of flow structure. The glass particles weld together, and sometimes so completely that the glassy matter becomes continuous. (Plate 63, fig. 1.)

2. Radial phase.—Felspar fibres develop in radial groups giving rise to a spherulitic structure. When this radial structure is developed it is restricted in most cases to a relatively small thickness of rock above that which has the vitreous phase. At Toki Point, Lake Taupo, the radial and vitreous phases occur in association in the same specimen. This association is found at low levels only, and is soon succeeded by rocks in which the radial phase only is found. (Plate 65, fig. 1; part of plate 64, fig. 2.)

3. Pectinate phase.—This phase occurs in the greater thickness of the deposit at Toki Point, Lake Taupo; and nearly all of that at Waimiha. It is poorly developed at Arapuni. When well developed, this has been called axiolitic structure, but its development has formerly been ascribed to wholly different causes. (Plate 64, fig. 1; part of plate 64, fig. 2.)

4. Plumose phase.—This is commonly the nature of the upper part of pulverulite rocks wherever they have been examined. This phase is usually combined with a rudimentary pectinate development. (Plate 63, fig. 2.)

B. Lenticulites.—The lenses of dark rock vary greatly in number and size. Good examples are found at Waikino and Putaruru.

1. Vitreous phase or wilsonite.—All particles large and small consist of glass; but the larger are penetrated throughout by sub-parallel gas pores of capillary dimensions. The smaller particles often bend round crystals. It apears that this phase constitutes the whole deposit of ignimbrite at Waikino. At Putaruru only the bottom two feet in the total thickness of forty feet are true wilsonite in the strict sense defined above. (Plate 66, fig. 2.)

2. Radial phase.—This is moderately developed at Putaruru. The large lensoid fragments of glass develop in this way far more readily than the small ones and than the fine grained matter. (Plate 67, fig. 2.)

3. Pectinate phase.—This is the main phase at Putaruru. The large lensoid fragments of glass develop the structure first; especially on the margin of the capillary pores by which they are traversed. (Plate 67, fig. 1.)

4. Plumose phase.—This has not been seen in this class of ignimbrite.

C. Lapidites.—The structure is dominated by the presence of angular fragments of rock of an acid nature. Examples are found at Hinuera, Paeroa Range, Mangakino Valley, and Mercury Bay.

1. Vitreous phase.—Restricted to the base of these deposits. The small particles of glass are not so strongly welded together in this type of rock as in the others. (Plate 62, fig. 1.)

2. Radial phase.—This has not been seen in any of the lapidites. Apparently the material was at too low a temperature for such crystallisation to take place.

3. Pectinate phase.—A rudimentary development of this phase is found directly above the vitreous phase at Hinuera and in the Paeroa Range. It is the dominant phase throughout the valley of the Mangakino.

4. Plumose phase.—Combined with a poorly pectinate phase in many localities. (Plate 68, fig. 2.)

Summary.

Ignimbrite is used as a name for a tufaceous rock of acid composition that has been formed from a "nuée ardente Katmaienne" in the nomenclature suggested by A. Lacroix. This type of rock has a wide occurrence over 10,000 square miles in the North Island of New Zealand.

Ignimbrites are distinguished from ordinary tuffs by the following characteristics:—

1. They have a uniform and normally fine texture.
2. There is an absence of bedding.
3. They show a pronounced prismatic jointing.
4. The rocks are coherent and have an effective solidity.
5. In micropreparations the rocks typically show "flow structure." This "flow structure" is explained as due to the bending of viscous glass shreds round previously existing crystals.

Ignimbrites are distinguished from lavas by the following field characters:—

1. The deposits have a disposition that is in ordinary instances approximately horizontal.
2. There is an absence of glassy selvages.
3. A scoriaceous surface is wanting.
4. Though there is no scoriaceous structure, the specific gravity is low.
5. A thin bed of extremely fine glass dust occurs below the formation in typical localities.
6. There is an increase in the specific gravity from the top to the bottom of each formation of the rock.
7. There is no indication of mass flow.

The following are the evidences of the high temperature of the ignimbrite material when it was deposited:—

1. Fragments of included charcoal are sometimes found.
2. The minute particles of glass of which the ignimbrites consist are welded together more or less completely.
4. Occasionally blebs of glass as much as 2 mm. in diameter have been formed from the welded shreds.
5. There is often a development of crystalline structure after the ignimbrite material reached the ground.

THE DEVELOPMENT OF AXIOLITIC AND SPHERULITIC STRUCTURES IN IGNIMBRITE DEPOSITS.

1. The upper portion of an ignimbrite deposit shows a feathery arrangement of glass shreds with incipient "devitrification."

2. There is a gradual increase in the distinctness and dimensions of the marginal felspar fibres and the central line of granular tridymite in the original glass shreds.

3. The feathery structure becomes less pronounced and gives place to a linear arrangement of the glass particles.

4. Distinct axiolitic structures become apparent.

5. A development of spherulites as well as axiolites becomes apparent.

6. In places at the base of a deposit the glassy shreds of various colours become fused together. In these blebs of glass there are spherical bubbles of gas as well as globulites and beaded trichites. In such material positive brown spherulites may develop in either the original glass shreds or in the newly formed colourless glass.

This complete transition has been found in all of its details at Motutere only, but in every place where the structure of an ignimbrite has been observed in microscopic preparations it has shown a gradual development of this type throughout its thickness.

In some spherulitic rhyolites the dusty lines which traverse the spherulites and other structures are thought to be inherited structures from the glass shreds of original ignimbrites.

It is maintained that deposition from a nuée ardente provides a satisfactory explanation for all of these features of occurrence and structure.

Illustrations.

Microscopic preparations of these ignimbrite rocks are extremely transparent and show very little contrast. It is therefore a matter of considerable difficulty to obtain negatives which illustrate the described features in a distinct manner. This difficulty is greatly increased by the extreme fineness of the details of the structure, while some of the main features are on a relatively coarse scale, but have an outline which is wanting in sharpness. In attempting to overcome the difficulties it has been found necessary to use rather larger plates than is usual.

Explanation of Illustrations.

Plate 62, Fig. 1.—Paeroa type of ignimbrite from the Paeroa Hills close to the crossing of the Rotorua-Taupo road. Lapidite. × 120. Broken crystals of felspar (oligoclase) and quartz and rarely hypersthene embedded in irregular shreds of glass of most unequal size and distributed without any regular arrangement. Some of the shreds are vesicular. Particles of glass are very lightly welded together. In some of the glass shreds minute needles of a mineral, presumably felspar, can be distinguished with their longer axes at right angles to the margin of the shred.

Plate 62, Fig. 2.—Ignimbrite from two feet above the base of the Hinuera occurrence. Lapidite. × 120 A few corroded crystals of quartz and more commonly crystals of felspar. The largest of these has some small inclusions of hypersthene. One large crystal of hypersthene with small crystals of magnetite included in it. Shreds of glass of varying sizes generally irregularly arranged, though there is slight bending round the crystal of hypersthene Portions of the larger glass shreds are brown in colour, probably because of minute gas bubbles which are too small to be seen separately.

Plate 63, Fig. 1.—Pulverulite. × 120. From near the base of the outcrop at Arapuni. A large crystal of oligoclase with corroded margin. The greater part of the photograph consists of shreds of colourless glass with parallel arrangement; c.f. *N.Z. Journal of Science and Technology*, vol. 13, p. 199, 1932. In this case the glass shreds after falling were sufficiently viscous for pressure to give them a parallel arrangement and to make them bend round the angles of the crystal, thus presenting an appearance of flow structure. The temperature, however, was not maintained for a sufficient time or other conditions were not favourable for the development of incipient crystallisation or devitrification in the glass shreds, and they are therefore moderately distinct.

Plate 63, Fig. 2.—Pulverulite, Plumose phase. × 120. From ten feet below the upper surface of the ignimbrite at Te Toki, near Motutere, on the east side of Lake Taupo. Then usual crystals of felspar are embedded in extremely

irregular shreds of glass in which a good deal of crystallisation or devitrification has taken place. This has obscured and largely obliterated their outlines. It can, however, be seen that they have no parallel arrangement. The pressure at this point so close to the surface of the deposit was not able to affect their form.

PLATE 64, FIG. 1.—Pulverulite. Pectinate phase. × 120. From Waimiha, Auckland-Wellington railway line, twenty miles north of Taumarunui, ten feet from the base of the deposit. The usual crystals of quartz and felspar, the former of which are much corroded. The shreds originally of glassy material have a marked parallel arrangement showing that they were viscous when deposited and yielded to pressure. The material of the shreds has crystallised, though the crystalline particles are so fine that they are seen indistinctly, even with high magnification. It can, however, be discovered that they have a margin of felspar fibres with their axes arranged at right angles to the surface of the shred. There is a central portion of minute tridymite tablets. The irregular vein-like structure is composed of small transparent spherulites. It is clear that the devitrification of the shreds took place after they fell and that the vein with its spherulites was also formed subsequently to deposition.

PLATE 64, FIG. 2.—Pulverulite. Radial phase. × 120. From 300 feet from the surface of the formation close to trig 1003 near Maraetai station, Perpetual Forests' estate. At one side of the photograph the parallel arrangement of the original glass shreds can be distinctly seen. The greater portion of the material has been crystallised into indistinct transparent spherulites. At one place a small deposit of iron oxide has darkened the rock. This rock, if examined separately, might well be called a spherulitic and axiolitic rhyolite with flow structure. Its field occurrence and upward variation to a typical glass shredded rock show clearly that it is an ignimbrite deposited at such a high temperature that the parallel arrangement of the shreds, formation of axiolitic structure, and of spherulites could take place after it fell.

PLATE 65, FIG. 1.—Pulverulite, Radial phase. × 120. From near the base of the formation at Te Toki, near Motutere, east side of Lake Taupo. In this rock the outline of the original glass shreds can be seen with difficulty. Their material has been completely changed into axiolitic and spherulitic structures. In the two hundred feet of outcrop between this rock and that shown in Plate 63, Fig. 2, microscopic preparations show a complete and gradual transition from the one type to the other.

PLATE 65, FIG. 2.—Ignimbrite from the base of the outcrop at Te Toki Point near Motutere, east side Lake Taupo. × 30. The greater part of the dark portion of this photograph consists of glass shreds which are too small and too indefinite in their outlines to be distinctly seen with such a low magnification. A, Lithophyse bordered with a narrow margin of dark brown spherulitic material. There are small crystals of tridymite T. projecting inwards from the margin of the lithophyse. Brown opaque spherulites are seen at S and S. Q. is quartz which is much corroded and in places is invaded with "gulfs" of colourless glass. Oligoclase felspar at F. At B.B. there

is a large area of colourless glass in which felspar and quartz are embedded. This has a distinctly frayed margin, and it is traversed with very indistinct dusty lines which in place can be distinguished as continuations of brown glass shreds which border the colourless glass. Numerous gas bubbles are embedded in the colourless glass.

PLATE 66, FIG 1.—A portion of Plate 65 enlarged 120 diameters. A portion of the side of the lithophyse shows the dark spherulitic matter with the projecting crystals of tridymite. The shreds of glass can now be distinctly seen between the lithophyse and the colourless glass bleb. The irregular border of the colourless glass has become distinct. It is seen to be traversed with perlitic cracks and it contains a large number of bubbles of gas.

PLATE 66, FIG 2.—Wilsonite from the base of the formation at Putaruru. × 120. The greater part of the photograph shows shreds of glass of an indefinite shape and with an indefinite arrangement and generally of a pale brown tint. One of the larger fragments of glass extends diagonally across the photograph and ends irregularly among the smaller glassy fragments. It is traversed by a large number of capillary pores. In hand specimens such glass fragments are black and have a vitreous lustre. The remainder of the rock is of a pale pink colour because of the presence of dispersed iron ore in it. Crystals of felspar and quartz are relatively rare in this rock. It is thought to be evident that this large fragment was in a viscous state when the material was deposited and that it owes its linear form in part at least to pressure of the material that was deposited on the top of it.

PLATE 67, FIG 1.—Wilsonite, Putaruru, from the same locality as the above, but from a point 25 feet above the base. × 120. In this specimen the disseminated glass shreds are devitrified. They have become changed into the usual felspar needles forming a comb-like structure at right angles to the margin of each shred, while the median line consists of a fine granular substance which is probably tridymite. The devitrification here as elsewhere is thought to be primary and to have occurred at the time of the deposit of the ignimbrite. It destroys the outline of the glass shreds, and the structure becomes so highly indefinite that it has become almost impossible to give an adequate idea of its nature in a photograph, especially as there is no parallel arrangement of glass fibres in this instance. A large inclusion of glass extends across the centre of the photograph comparable with that in the previous photograph, and capillary pores can still be distinguished in it, but its structure is now wholly axiolitic with felspar fibres everywhere, their axes at right angles to the line of the pores. At times, or even generally, the felspar fibres extend over considerable distances and cross the capillary pores, which are so fine that they do not attain the thickness of the section. The rock still has a pink tint due to finely disseminated iron oxide, while the inclusion is black, but is now largely wanting in the vitreous lustre.

PLATE 67, FIG 2.—Wilsonite from Putaruru ten feet from the base of the deposit. × 120. Here the original glass shreds have a parallel arrangement, but are quite devitrified—to such an extent, indeed, as to give an axiolitic appearance to the whole rock. The greater part of the photograph shows a

section through a black inclusion now mainly changed into a spherulitic structure. The margin of a large spherulite can be seen extending across a considerable width of the field. This structure somewhat obscures the original capillary development of the inclusion, though this can still be seen in the rather indefinite lines which extend across the imperfectly formed spherulite. Other parts of the inclusion have their structure to a great extent obscured by spherulitic and axiolitic development. The spherulites can actually be seen more distinctly in hand specimens than in microscopic preparations.

PLATE 68, FIG. 1.—Spherulitic rhyolite from road cutting on Mount Ngongotaha, Rotorua, on the road to the summit at an elevation of 700 feet. × 120. The radial structure in the large spherulties in this section is crossed by numerous narrow and discontinuous bands. These are of an indefinite nature, and it is thought that they are the remnants of an original ignimbrite structure. If this is the case, the ignimbrite material was clearly of such a high temperature when deposited that a complete spherulitic structure developed subsequently, and now these indefinite lines alone reveal the original ignimbrite structure.

PLATE 68, FIG. 2.—Lapidite from the junction of the Waikato and Mangakino Rivers. × 120. The ignimbrite material has a plumose structure, though but little of it is visible in this photograph. The greater part of the photograph is a portion of a typical soft inclusion which is characteristic of lapidites over a wide area. Apparently this inclusion had cooled to such an extent before it reached the ground that a crust had formed round it. It was therefore not compressed, and gaseous matter was unable to escape from it. Its internal structure is therefore soft and loose and is altogether wanting in that compact structure found in the black inclusions that have been illustrated in previous plates. In this case crystallisation took place in radial aggregates arranged on the inside of the hard marginal crust of the inclusion. The interior of the inclusion consists of loosely arranged spherulites which are composed of felspar fibres with which many tablets of tridymite are associated.

PLATE 69, FIG. 1.—Outcrop of pink wilsonite near Putaruru. The cliff is thirty-five feet high. FIG. 2.—Quarry face of pulverulite at Ngutuwera. The face of the rock is twenty feet high. FIG. 3.—Outcrop of lapidite at Hinuera. The cliff of lapidite is fifty feet high. The scale is given by a figure standing near the centre of the photograph.

PLATE 70, FIG. 1.—Gorge of the Waikato River at Maraetai, 5. The cliff face on the opposite side of the river is four hundred feet high, and is formed of a single deposit of ignimbrite. FIG. 2.—Part of the lower portion of the cliff in Fig. 1.

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Fig. 1.

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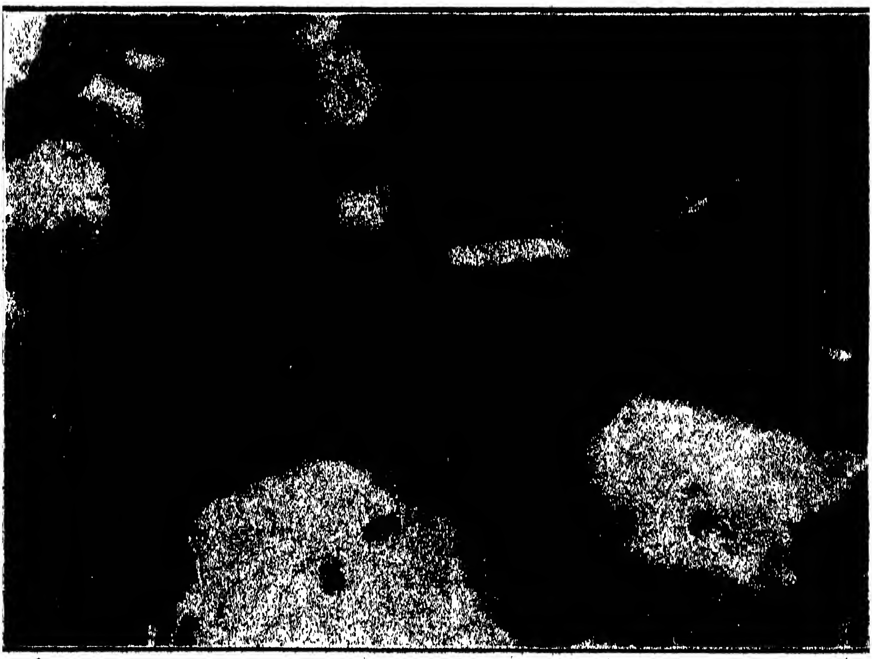

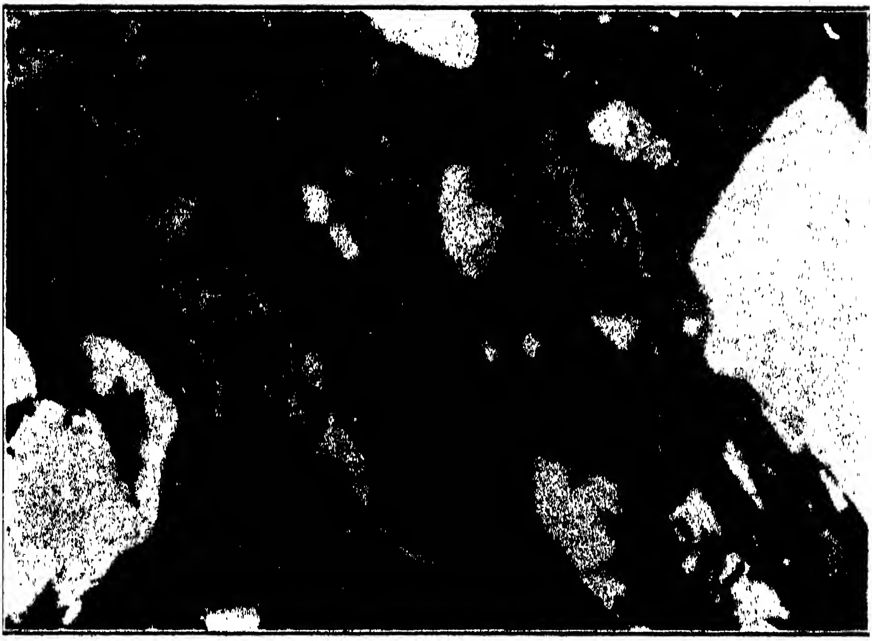

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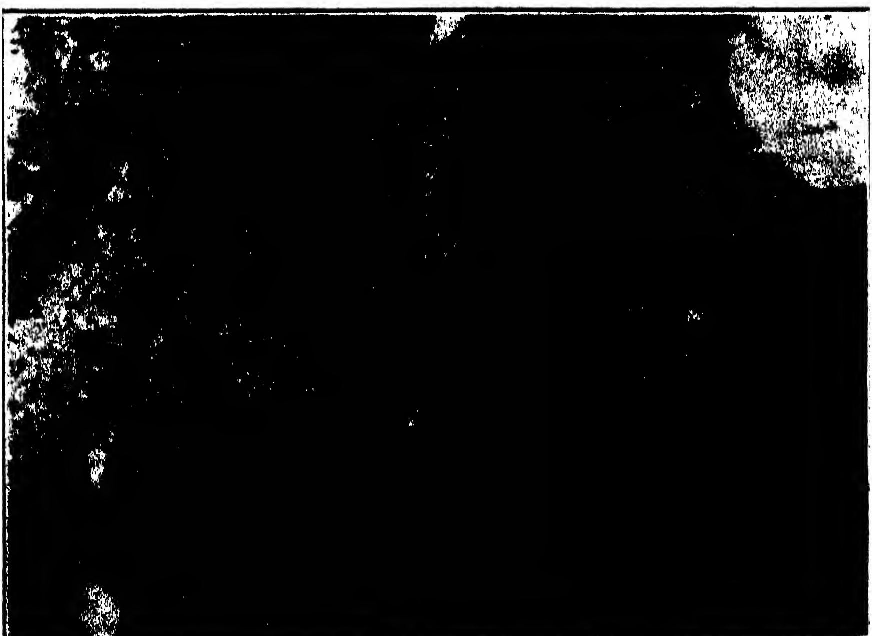

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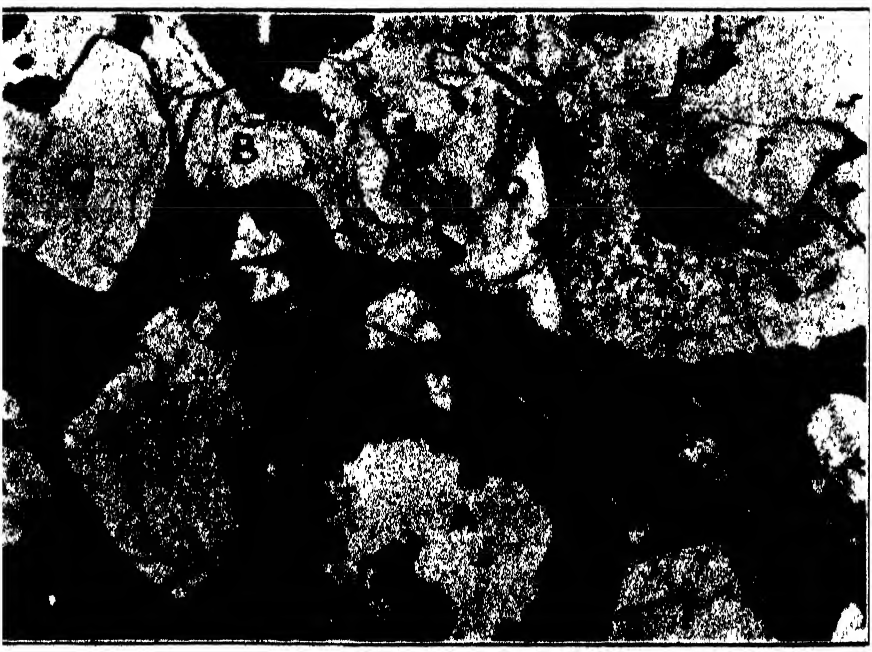

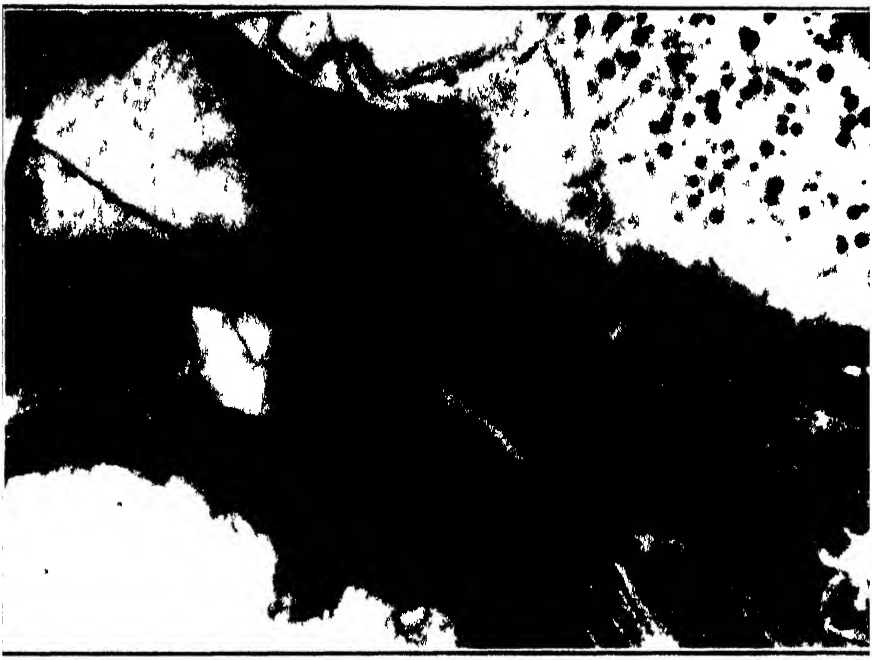

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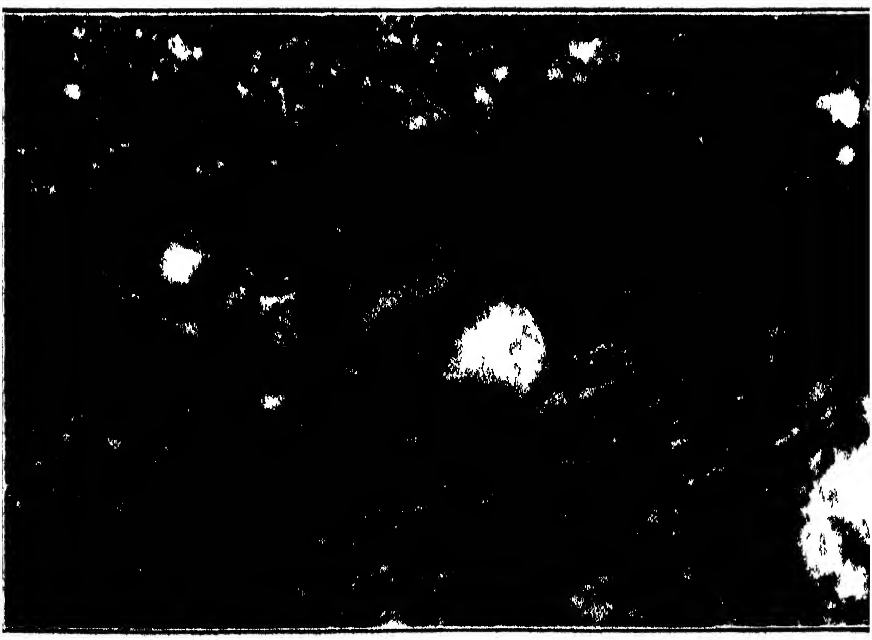

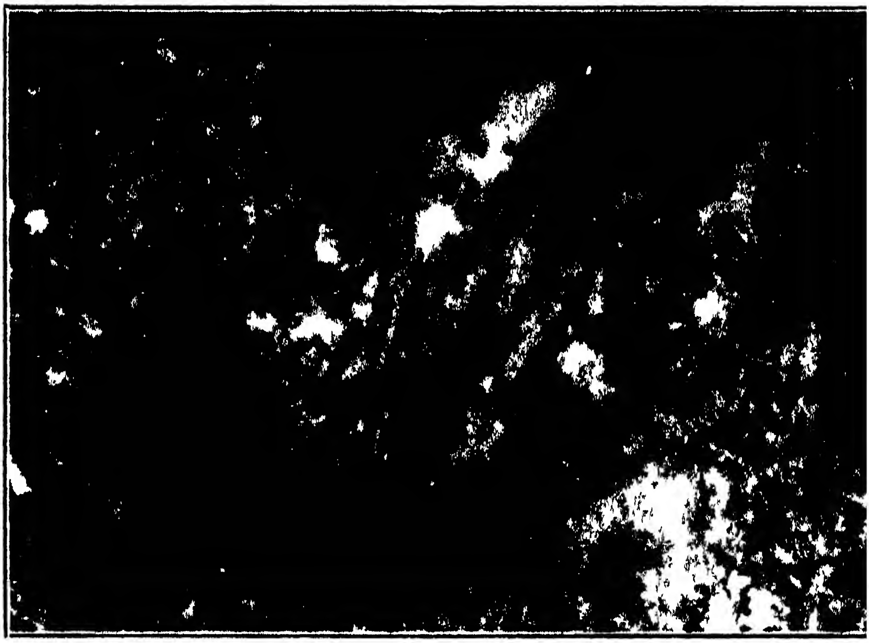

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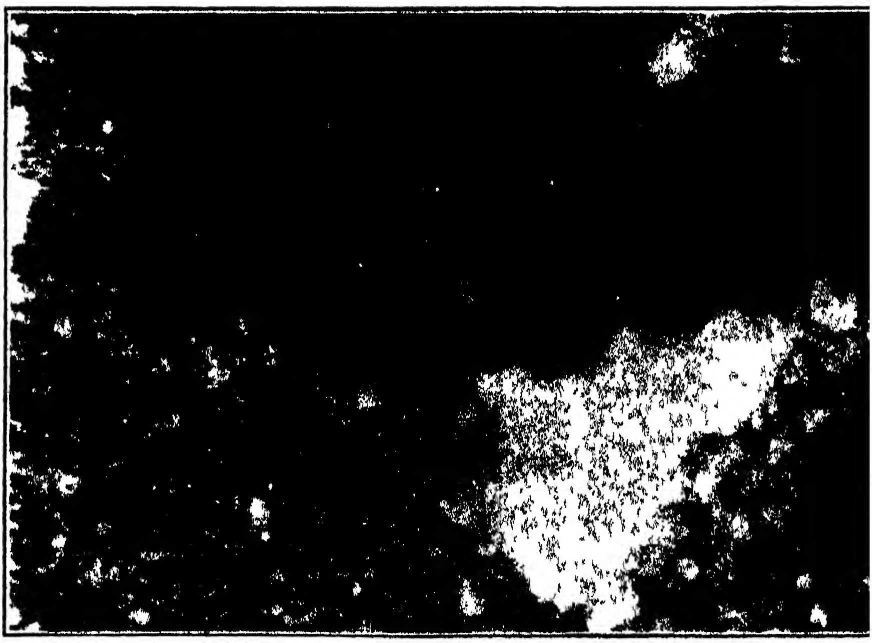

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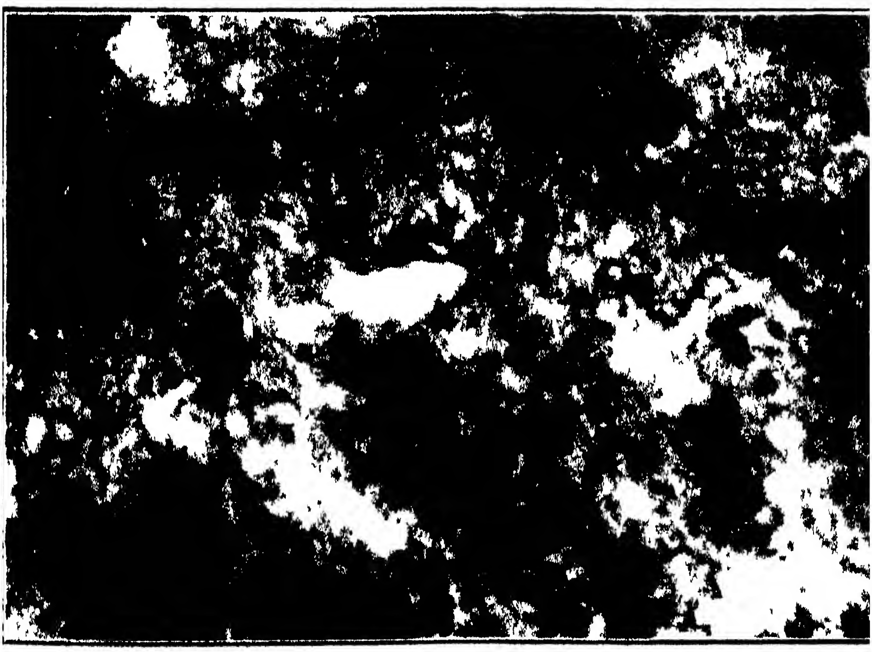

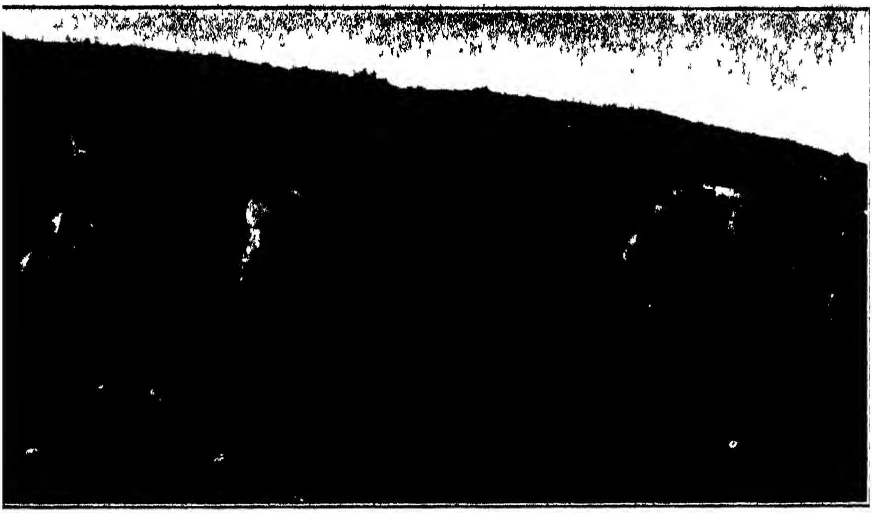

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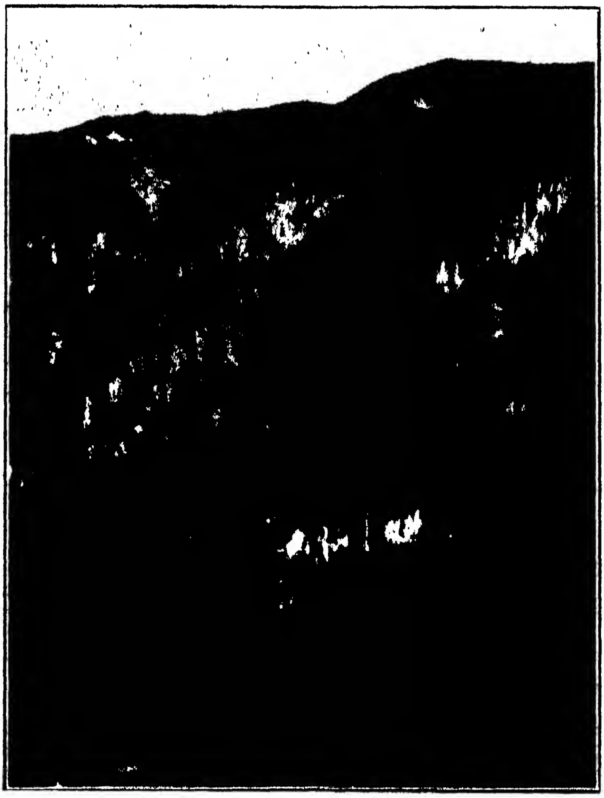

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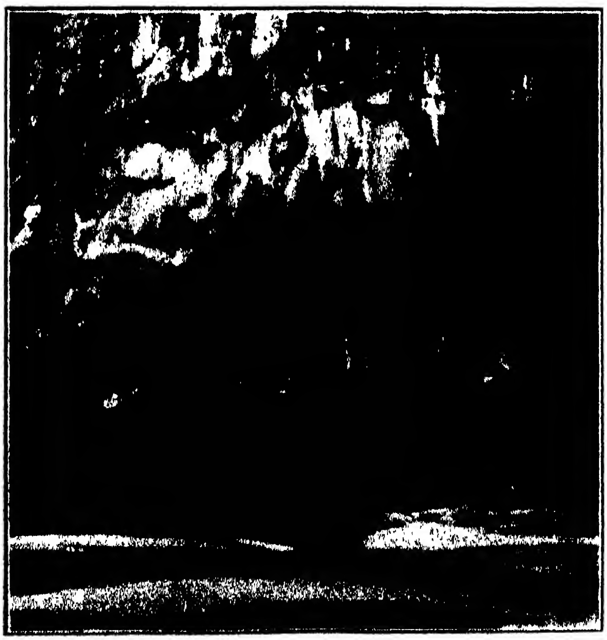

TRANSACTIONS

AND

PROCEEDINGS

OF THE

ROYAL SOCIETY OF NEW ZEALAND

VOL. 64
(Quarterly Issue)

PART 4, AUGUST, 1935.

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PART IV, 1935

THE
ROYAL SOCIETY OF NEW ZEALAND

ANNUAL MEETING, 16th MAY, 1934.

MINUTES.

The annual meeting of the Council of the Royal Society of New Zealand was held on Wednesday, 16th May, 1934, in the Council Room, Victoria University College, Wellington. Professor R. Speight, President, occupied the chair.

Present.—Representing the Government: Mr B. C. Aston. Mr M. A. Eliott, Dr E. Marsden, Mr W. R. B. Oliver; representing the Auckland Institute: Mr A. T. Pycroft, Professor H. W. Segar; representing the Wellington Philosophical Society: Dr E. Kidson, Professor H. B. Kirk; representing the Philosophical Institute of Canterbury: Dr C. C. Farr, Professor R. Speight; representing the Otago Institute: Dr F. J. Turner; representing the Hawke's Bay Philosophical Institute: Mr G. V. Hudson; co-opted member: Dr P. Marshall.

Apologies.—Apologies for absence were received from Professor James Park (Otago) and from Professor T. H. Easterfield (Nelson). Professor Park wrote stating that there was serious illness in his family, and Professor Easterfield wrote that he was suffering from influenza.

Honorary Patron.—A message written for the occasion of the inauguration of the Royal Society of New Zealand by His Excellency the Governor-General, who regretted his inability to be present at the meeting, was read by the President. On the motion of Dr Farr, seconded by Professor Segar, it was resolved that His Excellency be thanked for his inspiring message. On the motion of Dr Marshall, seconded by Dr Marsden, it was resolved that the message be printed in the Transactions. It was further moved by Dr Farr, seconded by Professor Segar, and carried, that the message be read at the commencement of the conversazione to be held that evening.

Tribute to Deceased Members.—The President referred to the deaths of several members who had passed away during the past year, namely, Mr G. M. Thomson, Professor D. M. Y. Sommerville, Sir Thomas Sidey, Mr Henry Hill, Sir Arthur Dudley Dobson, Mr J. P. Maxwell, Mr A. Dillon Bell, Sir Edward Mitchelson, Mr H. B. Matthews, Mr J. J. Bishop, Mr George Gray, and a past member of the Wellington Philosophical Society, Dr J. Mackintosh Bell. Also to the following honorary members: Professor W. Morris Davis and Professor J. W. Gregory. He asked the members of the Council to stand in respect to their memory.

The Late Mr G. M. Thomson.—On the motion of Professor Kirk, seconded by Dr Farr, the following resolution was carried in silence:

> "That the Royal Society of New Zealand place on record its sense of the great loss that has befallen this land through the death of Mr G. M. Thomson, who was, through a long life, an able, enthusiastic, and devoted worker in the field of science, an earnest and untiring public citizen, a courteous and upright gentleman, and that with the members of his family it express heartfelt sympathy."

The Late Professor D. M. Y. Sommerville.—On the motion of Dr Marsden, seconded by Dr Kidson, the following resolution was carried in silence:—

> "That the Council of the Royal Society of New Zealand places on record its deep sense of the loss incurred through the death of the late Professor D. M. Y. Sommerville, and desires to record its appreciation of the distinguished position he attained by his researches in Mathematics, his influence as a Professor at Victoria University College, his unselfish and efficient service to the Institute as Librarian and Editor, and the example of his high moral character and modest disposition. I therefore move that an obituary notice be recorded in the Proceedings of the Transactions, and that the resolution, with the Council's condolences, be transmitted to Mrs Sommerville."

Notices of Motion were then taken, and were dealt with later in the meeting.

Hector Award.—A statement was received from Dr Evans, convener of the Hector Award Committee, pointing out that the Committee was not yet in a position to give its recommendation. He referred to the death of Professor Sommerville, a member of the Award Committee, and stated that the vacancy thus caused had been filled by the appointment of Professor Carslaw, of Sydney. Dr Farr also outlined the action taken by the Committee. On the motion of Dr Marshall, seconded by Dr Farr, it was resolved that the Standing Committee be authorised to act when the Hector Award Committee's recommendation is received.

Amount of Hector Award.—On the motion of Mr Eliott, seconded by Mr Aston, it was resolved that the amount of the Hector Award for 1934 be £60.

Hamilton Award.—Dr Marshall moved the adoption of the Hamilton Award Committee's report, which is as follows:—

> "After careful consideration, we have decided to recommend that the Hamilton Prize be awarded to Mr L. C. King, M.Sc. Both of those who sent in papers have done a considerable amount of original work, and it happens that both have devoted themselves mainly to the study of palaeontology of local developments of tertiary rocks. Both have also done geological work in other fields. We consider that in such work

Mr King has shown more originality and he has travelled long distances and has thus made his observations of great comparative value. His papers are written in an attractive style.

(Signed) P. MARSHALL, Chairman."

14th May, 1934.

This was seconded by Mr Hudson and carried unanimously.

Amount of Hamilton Award.—On the motion of Mr Eliott, seconded by Mr Pycroft, it was resolved that the amount of the Hamilton Prize be £5.

Honorary Members.—The election of four honorary members was held, and resulted in the election of Mr E. C. Andrews, Dr P. Buck (Te Rangi Hiroa), Professor A. H. Compton, Professor J. B. Gatenby.

Declaration of Vacancies in Honorary Members' List.—The death of Professor W. Morris Davis was announced.

Declaration of Vacancies in Fellowship.—Two vacancies, caused by the death of Mr G. M. Thomson and of Professor D. M. Y. Sommerville, were declared.

Number of Fellows to be Elected in 1935.—On the motion of Dr Marsden, seconded by Professor Segar, it was resolved that two Fellows be elected in 1935

Title of Fellows.—On the motion of Dr Farr, seconded by Mr Pycroft, it was resolved that in future the title of Fellows be F.R.S.N.Z.

On the motion of Dr Marsden, seconded by Professor Segar, it was resolved that all present Fellows of the New Zealand Institute be deemed Fellows of the Royal Society of New Zealand.

Member Bodies' Reports and Balance Sheets.—The following reports and balance sheets were laid on the table:—

Auckland Institute, for the year ending 31st March, 1933

Otago Institute, for the year ending 31st October, 1933.

Wellington Philosophical Society, for the year ending 30th September, 1933.

Philosophical Institute of Canterbury, for the year ending 31st October, 1933.

Nelson Philosophical Society, for the year ending 30th September, 1933.

Hawke's Bay Philosophical Institute, for the year ending 31st December, 1933.

Professor Segar mentioned that he had a proof copy of the 1934 Report of the Auckland Institute.

The reports were received and were referred to the Hon. Treasurer for report.

Hawke's Bay Philosophical Institute.—It was reported that at the last meeting of the Standing Committee a telegram had been received from the Hawke's Bay Philosophical Institute asking permission to change its title to the Royal Society of New Zealand (Hawke's Bay branch), and to make use of the Society's badge. The Standing Committee had given the desired permission in regard to the change of title, and had informed the Hawke's Bay Institute that there was no objection to its using the Society's badge provided the words "Hawke's Bay Branch" were printed with the badge.

On the motion of Mr Hudson, seconded by Mr Oliver, it was resolved that the action of the Standing Committee be confirmed.

On the motion of Dr Kidson, seconded by Mr Eliott, it was resolved: "That the actual procedure in regard to the change of title of member bodies be referred to the Regulations Committee."

Report of the Standing Committee for the Year ending 31st March, 1934.

Meetings.—During the year five meetings of the Standing Committee were held, also a special meeting called to consider the Sidey Summer-time Award, the following being the record of attendance:—Mr B. C. Aston, Wellington, 6; Professor T. H. Easterfield, Nelson, 2; Mr M. A. Eliott, Palmerston North, 2; Dr C. C. Farr, Christchurch, 3; Mr G. V. Hudson, Wellington, 6; Dr E. Kidson, Wellington, 6; Professor H. B. Kirk, Wellington, 6; Dr E. Marsden, Wellington, 3; Dr P. Marshall, Wellington, 6; Mr W. R. B. Oliver, Wellington, 6; Mr A. T. Pycroft, Auckland, 2; Professor H. W. Segar, Auckland, 3; Professor R. Speight, Christchurch, 3; Dr F. J. Turner, Dunedin, 2.

Title.—On the 25th May, 1933, advice was received from His Excellency the Governor-General that His Majesty the King had approved of the Institute's title being changed to the Royal Society of New Zealand.

At first it was considered that this would necessitate merely an amending clause in the old Act, but the Crown Law Office intimated that an amending clause was impracticable, and that the time was opportune for the drafting of a new Act giving authority for the change of title and consolidating the old Act and amendments. The new Act, as drawn up, contains no new substantive provisions, the only alterations being of a machinery nature. Before it reached Parliament, a copy of the Bill was submitted to each member of the Council for his consideration, and all suggestions regarding it were carefully considered, and in some cases were adopted.

The Act was passed during the latter part of the last session of Parliament, and became effective on the 6th December, 1933.

To announce the change of title, a brief history of the New Zealand Institute from the time of its inception to the present was written up, and was issued to the press throughout New Zealand.

Regulations.—A sub-committee was set up to revise the regulations and to undertake any necessary action in connection with the change of title.

As this change necessitates an alteration in the wording on the various medals, it was considered advisable to add Professor Shelley's name to the sub-committee, and this was done at the last meeting of the Standing Committee on the 10th April, 1934.

At that same meeting the Standing Committee referred to the annual meeting the following proposed regulation which had been drafted by the Crown Law Drafting Office:—

> "A member of the Council or any Committee shall not vote or take part in the discussion of any matter before the Council or Committee in which he has directly or indirectly any pecuniary interest."

The Wellington Philosophical Society forwarded the following resolutions, which were referred to the annual meeting by the sub-committee:—

(1) "The number of Government appointees be reduced from four to two.

(2) "Any endowment money up to the amount at present received by the Institute from the Government for general expenses be definitely set apart for the publication of reports of scientific work as done at present through the Transactions."

Annual Meeting, 1934.—At a meeting of the Standing Committee held on the 10th April, 1934, a letter was received from the Secretary of the Wellington Philosophical Society as follows:—

". . . The Council of the Wellington Philosophical Society is desirous of marking the occasion of the first annual meeting of the Council of the Royal Society of New Zealand in some special way. It is suggested that this meeting extend over two days, and that the Wellington Philosophical Society act as host to the Council during such period as the Council is not engaged on the official business of the Royal Society. The proposals include the holding of a conversazione on the evening of the first day, a morning or afternoon session devoted to addresses and discussions of scientific interest, and perhaps visits to certain places in the immediate vicinity of Wellington. . . ."

Mr Callaghan attended the meeting and gave a more detailed account of what was proposed. It was suggested that possibly His Excellency the Governor-General might attend and deliver the inaugural address.

A sub-committee was set up to meet the representatives of the Wellington Philosophical Society, when the President's sanction to the proposals had been received. The sub-committee subsequently met, and it was intimated that His Excellency the Governor-General regretted his inability to attend the meetings owing to prior engagements in the Auckland district. It was decided that the business meeting should be held on the first day, the presidential address be given at the evening meeting, and other matters were left in the hands of the Council of the Wellington Philosophical Society. The Chairman expressed the appreciation of the Standing Committee at the action of the Wellington Philosophical Society, and thanked the Council for its kind invitation.

Council.—On the 25th August, the Institute suffered a very severe loss in the death of Mr G. M. Thomson. Mr Thomson had been a member of the Board of Governors since 1903, and his keen interest in the Institute and his valuable work as a member of the Board are an irreparable loss to the Society. To fill the vacancy thus occasioned, the Otago Institute elected Dr F. J. Turner, Lecturer in Geology at the University of Otago.

At the special meeting of the Board held on the 7th December, the President, Professor Speight, welcomed Dr Turner to the Board.

Mr Henry Hill.—News of the death of Mr Henry Hill, who was for some years a member of the Board of Governors, was also received with regret, and at a meeting of the Standing Committee held on the 23rd August the following resolution was passed: "That the Institute place on record its deep appreciation of the services rendered to the Institute and to science by the late Mr Henry Hill and its sense of the loss sustained by his death."

Finances.—The inadequacy of the annual grant of £500 has been commented upon on several occasions, and has been reflected during the year in the inability to publish certain papers of unusual length which were submitted by the authors for publication in the Transactions. The necessity for keeping down the cost of each part of the volume has prohibited the Standing Committee from even considering these papers, despite the fact that their inclusion might have enhanced the value of the Transactions.

An amount of £62, which had accumulated from unused or refunded research grants balances, was transferred by special sanction of Parliament to the Publications Fund, and is being used to cover the cost of publishing the results of researches undertaken with the aid of a grant.

The Finance Committee has met prior to meetings of the Publications Committee, and has stipulated what amount shall be spent on the various parts.

Publications.—The remaining three parts of Volume 63 were published, and Part 1 of Volume 64 is in the press. A good deal of delay occurred in the printing of the final parts of Volume 63, and much of this could have been avoided if certain authors had realised the necessity of promptitude in returning corrected proofs to the Hon. Editor. Those members who had ordered bound

copies of the volume in preference to the quarterly parts were justified in complaining of the delay in the receipt of their copies, but it is expected that there will be no further cause for complaint in this direction.

Parts 1, 2, and 3 of Volume 63 were laid on the tables of the Houses of Parliament on the 13th October, 1933, and Part 4 will be presented as soon as the Houses resume.

Hon. Editor.—It was with the greatest regret that it was learned on the 1st February, 1934, of the death of Professor D. M. Y. Sommerville, who had been Honorary Editor of the Transactions since the beginning of 1929.

Although Professor Sommerville had been in indifferent health, and on that account a few months previously had resigned the Honorary Editorship, his death came with tragic suddenness, as it was only the day previously that he had been in the Secretary's office discussing matters relevant to the Library and to the proposed supplementary edition of the Reference List of Scientific Periodicals.

In view of Professor Sommerville's resignation as Honorary Editor, at the special meeting held on the 7th December, Dr P. Marshall was appointed to the office, with Dr F. J. Turner, of Dunedin, as Associate Editor.

Reference List of Scientific Periodicals.—It is generally recognised that the Reference List edited by Mr Archey and published by the New Zealand Institute in 1927 is a most useful publication, but there is urgent need that it should be brought up to date. The Secretary has taken the preliminary steps for the compilation of a new edition, and it is hoped that the work will be completed during the coming year.

Index Trans. N.Z. Inst.—A decennial index to the Transactions is long overdue, as the last one published was for volumes 41-51. At a meeting of the Standing Committee held on the 7th December, the Vice-president reported that with the assistance of Major R. A. Wilson, steps had been taken for the preparation of an index of volumes 52-63. The Society is deeply indebted to Major Wilson for once again assisting in this direction. The index will be carefully scrutinised and checked before its publication.

Sales.—During the year no complete sets of the Transactions were disposed of, but, nevertheless, by the sale of odd volumes and bulletins and indexes the sum of £23 0s 10d has been added to the Endowment Fund.

Exchange List.—On the recommendation of the Library Committee, the following were added to the Exchange List:—

University of Western Australia.
Belfast Naturalists' Field Club.
University of North Carolina.
La Plata Museum, Argentina.
University of Tartu, Dorpat.
Budapest University Botanical Gardens.

Library.—On the recommendation of the Library Committee it was decided to proceed with binding as far as the amount in the Library Fund permitted, consequently certain sets have been prepared for binding. Unfortunately, however, the binder has been unable to procure the same buckram as he had previously used, and the ordering of new supplies has occasioned considerable delay.

A partial set of the Transactions was donated by Mr R. F. Blair, and Mr Aston has kindly presented certain volumes of the old reports of the Agricultural Department. The thanks of the Society are accorded to these gentlemen for their action.

The Library is being used extensively by the staff and advanced students of Victoria University College, and is much appreciated by them. The Library greatly misses the willing service and advice of its Honorary Librarian, the late Professor Sommerville.

It was intimated through the press that a representative of the Carnegie Corporation of New York intended making a survey of the public and other libraries in New Zealand. The Carnegie Corporation was written to and asked that its representative should include the Society's Library in his survey, and some of the most pressing needs of the Library were pointed out.

Member Bodies.—The following reports and balance sheets have been received:—

Auckland Institute, for the year ending 31st March, 1933.
Otago Institute, for the year ending 31st October, 1933.
Wellington Philosophical Society for the year ending 30th September, 1933.
Philosophical Institute of Canterbury, for the year ending 31st October, 1933.
Nelson Philosophical Society, for the year ending 30th September, 1933.
Hawke's Bay Philosophical Institute for the year ending 31st December, 1933.

Fellowship.—On the 3rd August, 1933, Dr H. G. Denham was gazetted a Fellow of the New Zealand Institute.

At the last annual meeting the number of Fellows had reached forty, the limit laid down in the Regulations, consequently there will be no election at the 1934 meeting. At that meeting, however, it will be necessary to declare two vacancies owing to the death of Mr G. M. Thomson and of Professor D. M. Y. Sommerville.

Honorary Members.—Four vacancies in the list of honorary members were declared at the last annual meeting. For these vacancies eleven nominations have been received from the member bodies for election at the annual meeting.

Hector Award.—Last year two awards for the Hector Medal and Prize were made. At a meeting of the Wellington Philosophical Society on the 23rd August, the President, Professor Speight, presented the Hector Medal and Prize to Dr J. Marwick, while at a function in the Otago Institute the Chancellor of the University of Otago presented Dr W. N. Benson with a similar medal and prize.

At the last meeting of the Standing Committee it was decided to ask Dr Carslaw, of Sydney University, to act on the Hector Award Committee for 1934 in place of the late Professor Sommerville. Dr Carslaw has signified that he will be pleased to act on this committee.

A recommendation: "That the various award committees, in making their reports, should set out briefly the grounds on which their recommendation is made" was received from the Wellington Philosophical Society and adopted at a meeting of the Standing Committee on the 23rd August.

T. K. Sidey Summer-time Award.—A few days after the last annual meeting news was received with great regret of the death of Sir Thomas Sidey, founder of the Summer-time award.

At a meeting of the Standing Committee held on the 23rd August several letters of protest in regard to the Sidey Summer-time award made at the last annual meeting were received and subsequently were circulated to members of the Council for consideration.

As the outcome of later developments, a special meeting of the Board was called on the 7th December to receive a unanimous report from the Summer-time Award Committee. That report recommended that a special prize be given to Mr Hudson and the first Summer-time award be given to Lord Rutherford, in view of the fact that Lady Sidey had given an assurance that she would provide two prizes, and that Mr G. V. Hudson would relinquish his claim to the award made at last annual meeting. After some discussion, it was resolved:

(1) That a special Sidey Medal and prize of £100 be awarded to Mr Hudson in recognition of his pioneer work in daylight saving.

(2) That the first Sidey Summer-time Medal and prize be awarded to Lord Rutherford.

Subsequently a cheque for £200 was received from Lady Sidey, and Lord Rutherford signified his pleasure in accepting the first Sidey Summer-time award.

The Institute expressed its heartiest appreciation of Lady Sidey's action in providing a special prize as well as the amount of the first award.

Carter Bequest.—At last annual meeting the report presented by the Carter Observatory Committee was referred back to the Standing Committee with authority, if it were considered advisable, to continue negotiations with the City Council for the purchase of the City telescope or some other, and to take such steps as it may think desirable to establish a Carter Observatory on lines such as those indicated in the report of the Committee.

At a well-attended meeting of the Standing Committee held on the 23rd August a lengthy discussion on the proposals submitted in the report took place. At that meeting also a deputation from the Astronomical Section of the Wellington Philosophical Society urged the carrying out of the proposals. Many arguments for and against the proposals were brought forward, and opinions regarding the proposed site were far from unanimous.

Finally it was resolved: "That the Standing Committee take immediate steps to ascertain whether the words of the Carter Will, 'in or near Wellington,' may be altered to allow of the erection of the observatory outside these limits, and the method and cost of making the Will effective in that direction.'"

A legal opinion has been received, and will be submitted to the annual meeting.

Hutton Grants.—Four applications for grants from the Hutton Fund were considered at a meeting of the Standing Committee on the 10th April, 1934. Mr L. C. King applied for £25 for geological research in the Marlborough district. Messrs R. A. Falla and A. W. B. Powell applied for £50 for research on the molluscan and bird fauna of the Sub-Antarctic Islands of New Zealand. Dr C. C. Caldenius, of Stockholm, applied for a grant to assist in the investigation of varves in New Zealand. Mr W. R. B. Oliver applied for £75-£90 to assist him in publishing a Monograph on the Genus *Coprosma*.

The Standing Committee recommended to the annual meeting that Mr King be granted £25; Messrs Falla and Powell, £40; Mr Oliver, £50.

It was further recommended that at the 1935 annual meeting, Dr Marshall, whose application was too late for consideration by the 1934 meeting, be granted £25 for apparatus for measuring microscopic crystals.

Permanent Records.—The work of establishing a permanent record of those who have been prominent members at some period during the sixty-seven years of the Institute's existence is progressing, and with the co-operation of the Dominion Museum it is hoped to procure as many photographs of these as is possible.

Earthquake-proof Building Construction.—At a meeting of the Standing Committee held on the 23rd August, the President, Professor Speight, stated that he considered the Institute should take a lead in urging upon the Government the necessity of introducing legislation to revise the building regulations with a view to minimising earthquake and fire risk. A sub-committee consisting of Dr Kidson (convener), Dr P. Marshall, Dr M. A. F. Barnett, and Mr F. W. Furkert was set up to bring the matter before the Government.

Subsequently a deputation headed by the President, Professor Speight, and comprising members of the Institute, civil engineers, architects, and builders and contractors, waited upon the Prime Minister and urged that the Building Construction Bill should be proceeded with. Mr Forbes gave an assurance that the Bill would be placed before Parliament.

Later, however, it was learned that instead of proceeding with the Bill, Cabinet decided to proceed along the lines of existing legislation which empowers the Government to draft model by-laws, etc., which will become part of the by-laws of all municipal authorities concerned. Dr Kidson has reported that, on learning of this, Professor Speight wrote to the Prime Minister expressing the concern of the New Zealand Institute at this, and pointing out that it was because of the inadequacy of the suggested measures and the existing machinery that the deputation had waited on him on the 5th October. The Prime Minister replied on the 12th December that he appreciated the anxiety that there should be a minimum standard of structural strength in connection with buildings in areas liable to earthquake, but that after careful consideration it had been decided to proceed along the above lines. He wrote: ". . . You will appreciate that these proposals are a definite step in the direction of more adequate protection against earthquake, and it is regretted that the more complete and involved arrangements contemplated by the Building Construction Bill cannot at present be given effect to owing to considerable opposition brought forward."

The Committee is considering what action might be taken to induce the Government to reverse its decision, and it is anticipated that definite proposals will be brought before the annual meeting for consideration.

Wild Life Control.—In August the New Zealand Forestry League wrote asking the Institute to support it in a request to the Commissioner of State Forests to set up a Royal Commission to inquire into the destruction of forests by plant-eating animals. The Native Bird Protection Society wrote on the same subject, but expressed the view that there was no need to incur expense in the setting up of a Commission, as there was abundant evidence of the destruction caused by these animals. It considered that the only remedy was extermination, but in the event of a Royal Commission being set up, the whole question of wild life control should be the subject considered, and that the Commission should consist of five, not three experts as suggested by the Forestry League.

The Standing Committee considered these letters, and approved of the suggestion that a Royal Commission should be set up in order that the whole subject of wild life control should be investigated.

The Nelson Philosophical Society has also asked the Council of the Royal Society of New Zealand to consider the advisability of making strong recommendations to the Government to the effect:—

(1) That the menace to our native forests from reckless burning, and to a much greater extent from the destruction caused by deer and other animals, is much more serious than is as yet realised by the general public.

(2) That the results of the wholesale destruction of our forests now taking place will, if it is allowed to continue, constitute a national calamity of the first magnitude at no distant date. The choking up of our river-beds and the ruination of our plains as the result of the denudation of our mountains is already raising serious problems in the Nelson and other districts.

(3) That much more drastic steps should be taken to deal with this menace than have been adopted up to the present.

(4) That no native forests should be allowed to be destroyed until experts have examined the ground and have certified that the land is suitable for agricultural, pastoral, mining, or similar purposes, and that it is not contrary to the national interest for the forest to be cleared.

(5) That large areas of Provincial State Forests could, and should now, be declared permanent State forests.

At a meeting of the Standing Committee held on the 10th April the matter was referred to the annual meeting for consideration.

Kermadec and Auckland Islands.—Advice was received on the 6th April from the Lands and Survey Department that the pastoral license held by Messrs Moffatt Bros. had recently expired, and the opportunity was taken by the Department of reserving Auckland, Rose, Disappointment, Enderby, and Ewing Islands for the preservation of native flora and fauna. As Adams Island was reserved in 1910, the whole of the Auckland group is now under reservation. The Kermadec Islands, with the exception of a small freehold area on Sunday Island, have also been reserved for the same purpose.

The Standing Committee expressed its appreciation of the action of the Government.

Portobello Marine Fish Hatchery.—At a meeting of the Standing Committee held on the 7th December, Professor Kirk drew attention to the fact that the Government grant to the Portobello Fish Hatchery had been so reduced that it was not possible for it to employ a biologist. It was resolved that representation be made to the Government pointing out the necessity, at the first opportunity, of making provision for the appointment of a trained biologist.

The Minister of Marine replied that the views of the Institute have been noted, and they will be useful when the position of the Fish Hatchery is being reconsidered next year.

Pacific Science Congress.—The general secretary of the Fifth Pacific Science Congress wrote forwarding a copy of a minute of the final meeting of the Congress as follows: "Whereas no invitation has been received by the Pacific Science Association for the Sixth Congress, and whereas it is expedient to maintain an active committee in charge in order to find a place for the next meeting, and to give assurance that the work of the Pacific Science Association will

not be neglected in the interim, it is resolved that this final meeting of the Pacific Science Council in Vancouver, B.C., Canada, approve the appointment of a general Hold-over Committee under the present chairman, Dr H. M. Tory, for this purpose, and that the Committee be comprised of one representative from each of the countries that have taken an active interest in the work of the Pacific Science Association, including not only those which are members of the Pacific Science Council, but also Hong Kong, Fiji, Straits Settlement, and Federated Malay States, Mexico, and Siam, and that the Committee be given power to add to its numbers."

It was decided to ask Professor Speight to sit on this Committee.

Australian and New Zealand Assoc. Adv. Science.—At a meeting of the Standing Committee held on the 10th April, 1934, it was resolved to ask the Auckland Institute what preliminary steps had been taken in regard to the 1937 meeting of the Association, which is to be held in Auckland.

Overseas Meetings and Celebrations.—Dr J. G. Myers and Mr E. Meyrick both wrote regretting their inability to attend the celebrations in connection with the Entomological Society of London. Dr Myers explained that his work was keeping him in South America.

Dr J. Mackintosh Bell, who represented the Institute at the Geological Congress in Washington last year, wrote on the 30th October that the Congress was a very interesting one, and a wide field of geological subjects was covered in the papers and discussions, and although none of the papers dealt directly with New Zealand, one or two references were made as regards outstanding features there.

News of the death of Dr Bell on the 31st March was received with great regret.

An invitation to the International Geological Congress in Warsaw was received, and Dr Benson was asked to represent the Institute if he found it possible to attend. An invitation to the 150th anniversary of the Asiatic Society of Bengal was received too late for action.

Institute of France.—An application was received from the Institute of France for an exchange of medals. It was decided to accede to this request, and specimens of the Society's three medals were forwarded.

A letter appreciating the action of the Society and advising that four medals were being forwarded in exchange has been received, but the medals have not yet come to hand.

Accommodation in New Museum Building.—Although it is an understood thing that the Society's Library and office will be housed in the new buildings, the National Art Gallery and Dominion Museum Act makes no provision for this, and it was considered that a definite agreement regarding the Society's tenure should be arranged. It was decided that Professor Kirk, Dr Marshall, and Mr Aston should go into the matter with the Board of Trustees and make some suitable terms.

The Late Mr G. M. Thomson's Work on Crustacea.—The question of the publication of this work was discussed, and it was resolved that the matter be left in the hands of Mr Oliver, the President, and Mr Archey for consideration and report.

Roll-call, Annual Meetings.—At a meeting of the Standing Committee held on the 28th June, the following resolution was carried:—

> "That at future meetings of the Board of Governors there be a roll-call in the afternoon as well as in the morning."

The report of the Standing Committee was considered clause by clause, and on the motion of Professor Speight, seconded by Mr Pycroft, was adopted.

New Regulation.—On the motion of Mr Eliott, seconded by Professor Kirk, is was resolved that the following proposed clause drafted by the Law Drafting Office be adopted:—

> "A member of the Council or any Committee shall not vote or take part in the discussion of any matter before the Council or Committee in which he has directly or indirectly any pecuniary interest."

Medals and Seal.—It was reported that at the last meeting of the Standing Committee a report had been received from Professor Shelley in regard to the proposed alteration of the Society's medals made necessary by the change of title, and the Standing Committee recommended to the annual meeting that Professor Shelley's report and sketch be submitted to Mr A. G. Wyon, maker of two of the original dies, for his approval or comment. On the motion of Professor Kirk, seconded by Dr Farr, it was resolved: "That Professor Shelley be thanked for his report, and that the recommendation of the Standing Committee be approved."

In regard to the Society's seal, it was reported that the Standing Committee had asked the Regulations Committee "to examine the seal of the Royal Society of London and other similar societies with the object of arriving at the requisites for inclusion in a seal for the Royal Society of New Zealand, introducing some feature distinctive of New Zealand." The action of the Standing Committee was confirmed.

Proposals by Member Bodies.—Dr Farr asked that opportunity be given to the meeting to consider the proposals submitted by the Philosophical Institute of Canterbury. It was stated that the proposals referred to had been sent by the Philosophical Institute of Canterbury to the Wellington Philosophical Society in reply to the latter's circular. No official communication had been received from the Philosophical Institute of Canterbury, merely a copy of the letter to the Wellington Philosophical Society. Dr Farr stated that the Philosophical Institute of Canterbury had desired to have the Act amended, and had not been given the opportunity when the new Act was drawn up. Mr Aston explained that copies of the Bill had been circulated to members of the Council for suggestions, but the Bill was confidential until it came before the House, and it could not be discussed publicly.

Dr Marsden further explained that the new Act had been purely of a machinery nature and that it would have been impracticable to introduce new matter.

A letter from the Wellington Philosophical Society, dated 26th October, 1933, embodying two proposals, was read. After some discussion, on the motion of Professor Kirk, seconded by Mr Oliver, it was resolved to refer the letter to the Standing Committee for report. On the motion of Mr Pycroft, it was resolved that the Standing Committee should approach member bodies for information regarding suggested amendments.

Wild Life Control.—In connection with the question of wild life control and the setting up of a Royal Commission to consider the subject, it was resolved, on the motion of Dr Kidson, seconded by Mr Pycroft, that a committee consisting of the President, the Vice-president, Professor Kirk, Dr Marsden, Mr Oliver, Mr E. F. Stead, and Mr R. A. Falla be set up to co-operate with other interested societies and report to the Standing Committee. The committee to have power to co-opt other members, and the Standing Committee to have power to take action.

Mr Pycroft mentioned that the Auckland Institute would support any action in the extermination of opossums as well as of deer.

Mr G. M. Thomson's Work on Crustacea.—Mr Oliver, convener of the sub-committee set up to consider the completion of the late Mr Thomson's work on the Crustacea, reported that it was considered that some qualified person should continue the work, but that at the present time no one qualified was available. Miss Margaret Thomson proposes to spend a year in England, part of the time studying crustacea under Dr Calman at the British Museum, and she hopes then to have sufficient qualifications and to be in a position to finish the book on New Zealand Crustacea. In the circumstances, the committee recommends that no action be taken by the Royal Society of New Zealand at present. Mr Oliver moved the adoption of this report, which was seconded by Professor Kirk and carried.

Earthquake Building Construction.—Dr Kidson, convener of the sub-committee set up to urge the Government to introduce a Building Construction Bill last session of Parliament, reported that further action had been taken by the committee, and he produced a statement and a circular which the committee proposed to circulate to all members of the House and to other interested persons. He moved that the President, Professor Speight, sign this statement, and that the sub-committee be given authority to circulate it. Dr Kidson read the circular, but the statement was a lengthy one, and, on the motion of Dr Farr, it was resolved that the matter be postponed until the afternoon session in order that members might have an opportunity to read the statement.

Honorary Treasurer's Report.

The balance sheet for the twelve months ending 31st March, 1934, shows a balance of assets over liabilities of £1028 12s 7d as compared with £1067 11s 11d on 31st March, 1933.

The main feature of the financial position is that the Society has lived within its means. Owing to the use of the pruning knife, the cost of printing the Transactions has been kept down to a level corresponding to the amount available. The total cost of Volume 63 was £586 15s 3d, and the Finance Committee has authorised the expenditure of £262 on Parts 1 and 2 of Volume 64.

The Trust Accounts are in a satisfactory condition. The Carter Bequest Capital Account stands at £9509 15s 1d, an increase of £563 for the year, and as a result of the legal opinion obtained, this Fund will now remain intact until it has grown sufficiently to produce an income adequate to meet the wishes of the testator.

Once more I have pleasure in stating that the books and accounts have been kept up to the usual high standard by the Secretary.

M. A. Eliott,
Honorary Treasurer.

The Royal Society of New Zealand.

Statement of Receipts and Expenditure for the Year ending 31st March, 1934.

Receipts.

	£	s.	d.
Balance as at 31st March, 1933	1,464	3	2
Annual Grant	500	0	0
Publications Vote from Research Fund	62	18	10
Levy, Volume 63	133	4	6
Travelling Expenses; share from member bodies	19	17	2
Sales of Publications	23	0	10
Favourable Exchange	2	15	7
Research Grant Refund	0	0	8
Interest Post Office Savings Bank	41	9	4
Carter Bequest Interest	376	14	7
Hector Memorial Fund Interest	51	16	5
Hutton Memorial Fund Interest	56	5	7
Carter Library Legacy Interest	8	6	9
Hamilton Memorial Fund Interest	2	9	6
Endowment Fund Interest	32	3	5
T. K. Sidey Summer-time Fund Interest	19	13	10
T. K. Sidey Summer-time Fund—Donation	200	0	0
Trust Funds transferred to Bank of New Zealand	648	11	9
	£3,643	11	11

Expenditure.

	£	s.	d.
Otago Daily Times (Vol. 63—Parts 2, 3, and 4)	476	18	7
Stationery	13	0	10
Salary	240	0	0
Travelling Expenses	48	18	3
Subscription Int. Council Scientific Union	5	9	0
Petty Cash	10	12	11
Charges (Insurance, Bank Audit, etc.)	9	9	1
Library Binding	4	16	0
Research Grants Instalments	11	5	7
Research Grants to Publications Fund	62	18	10
Trust Funds—Audit Charges	2	0	0
Hutton Grants Instalments	40	0	0
Hector Prizes and Engraving Medals	80	17	3
Interest credited direct to Trust Accounts	515	6	8
Trust Funds Invested	599	2	6
Balance as under	1,522	16	5
	£3,643	11	11

	£ s. d.	£ s. d.	£ s. d.
Bank of New Zealand	76 17 2		
Less Unpresented Cheques, £1 3s 10d and £1 17s 6d	3 1 4		
		73 15 10	
Post Office Savings Bank		1,440 10 0	
			1,514 5 10
Petty Cash in Hand			8 10 7
			£1,522 16 5

M. A. Eliott,
Hon. Treasurer.

The Audit Office, having examined the balance sheet and accompanying accounts required by law to be audited, hereby certifies them to be correct.

J. H. Fowler,
Deputy Controller and Auditor-General.

THE ROYAL SOCIETY OF NEW ZEALAND.

STATEMENT OF ASSETS AND LIABILITIES AS AT 31ST MARCH, 1934.

Liabilities.

	£	s.	d.
Carter Bequest Capital Account	9,509	15	1
Hector Memorial Fund Capital Account	1,184	18	1
Hutton Memorial Fund Capital Account	1,314	8	6
Hamilton Memorial Fund Capital Account	61	8	9
Carter Library Legacy Capital Account	100	0	0
T. K. Sidey Summer-time Fund Capital Account	510	18	9
Endowment Fund Capital Account	984	4	6
Carter Bequest Revenue Account	91	12	0
Hector Memorial Fund Revenue Account	86	8	9
Hutton Memorial Fund Revenue Account	277	14	0
Hamilton Memorial Fund Revenue Account	6	19	7
Carter Library Legacy Revenue Account	75	5	5
T. K. Sidey Summer-time Fund Revenue Account	282	10	6
Endowment Fund Revenue Account	135	9	11
Library Fund	151	9	10
Research Grants Fund	142	6	2
Balance of Assets over Liabilities	1,028	12	7
	£15,944	2	5

Assets.

	£	s.	d.
Inscribed Stock	13,557	8	8
Bank of New Zealand	73	15	10
Post Office Savings Bank	1,440	10	0
Reserve Bank Shares	36	0	0
Petty Cash in Hand	8	10	7
Carter Bequest—P.O.S.B. Account	148	9	6
Hector Memorial Fund—P.O.S.B. Account	88	11	0
Hutton Memorial Fund—P.O.S.B Account	278	19	0
Hamilton Memorial Fund—P.O.S.B. Account	68	13	4
Carter Library Legacy—P.O.S.B. Account	75	12	11
T. K. Sidey Summer-time Fund	94	11	5
Outstanding Accounts	73	0	2
	£15,944	2	5

THE ROYAL SOCIETY OF NEW ZEALAND.

REVENUE ACCOUNT FOR THE YEAR ENDING 31ST MARCH, 1934.

Expenditure.

	£	s.	d.
Printing and Stationery	489	19	5
Salary	240	0	0
Travelling Expenses—Society's Share	29	1	1
Charges	12	2	6
Petty Cash	10	12	11
Sales credited to Endowment Fund	23	0	10
Balance	1,028	12	7
	£1,833	9	4

Income.

	£	s.	d.
Balance at 31st March, 1933	1,067	11	11
Annual Grant	500	0	0
Transferred from Unused Research Grants to Publications Fund	62	18	10
Administration Fees Trust Accounts	5	17	2
Sales of Publications	15	6	11
Levy Vol. 63, Trans. N.Z. Inst.	181	14	6
	£1,833	9	4
By Balance	£1,028	12	7

The Royal Society of New Zealand.

Trust Accounts for the Year ending 31st March, 1934.

Carter Bequest.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Interest Invested ..	563	2	6	By Balance, 31/3/33 ..	279	14	11
Administration Expenses	1	15	0	Interest	375	14	7
Balance	91	12	0	Premium Refunded ..	1	0	0
	£656	9	6		£656	9	6
				By Balance	£91	12	0

Hector Memorial Fund.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Administration Expenses	1	5	0	By Balance, 31/3/33 ..	116	14	7
Prizes (Drs Benson and Marwick)	80	0	0	Interest	51	16	5
Engraving Medals ..	0	17	3				
Balance	86	8	9				
	£168	11	0		£168	11	0
				By Balance	£86	8	9

Hutton Memorial Fund.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Grants	40	0	0	By Balance, 31/3/33 ..	262	13	5
Administration Expenses	1	5	0	Interest	56	5	7
Balance	277	14	0				
	£318	19	0		£318	19	0
				By Balance	£277	14	0

Hamilton Memorial Fund.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Half Interest to Capital	1	4	9	By Balance, 31/3/33 ..	5	19	10
Administration Expenses	0	5	0	Interest	2	9	6
Balance	6	19	7				
	£8	9	4		£8	9	4
				By Balance	£6	19	7

Carter Library Legacy.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Administration Expenses	0	7	6	By Balance, 31/3/33 ..	67	6	2
Balance	75	5	5	Interest	7	15	2
				Premium Refunded ..	0	11	7
	£75	12	11		£75	12	11
				By Balance	£75	5	5

T. K. Sidey Summer-time Fund.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To One-tenth Income to Capital	1	19	5	By Balance, 31/3/33 ..	66	0	9
Administration Expenses	1	4	8	Interest	19	13	10
Balance	282	10	6	Donation from Lady Sidey	200	0	0
	£285	14	7		£285	14	7
				By Balance	£282	10	6

Endowment Fund.

Dr.	£ s. d.	*Cr.*	£ s. d.
To Reserve Bank Shares ..	36 0 0	By Balance, 31/3/33	76 11 4
Administration Expenses	1 15 0	Interest	32 3 5
Balance	135 9 11	Interest from General Account	41 9 4
		Sales of Publications ..	23 0 10
	£173 4 11		£173 4 11
		By Balance	£135 9 11

Hon. Treasurer's Report and Statements.—The Hon. Treasurer, Mr M. A. Eliott, moved the adoption of his report and the balance sheet and statements which had been audited and certified to; seconded by Professor Segar, and carried.

Auckland Islands.—Mr Pycroft mentioned that a company had applied for a lease of part of the Auckland Islands for the purpose of silver fox farming, but the Government had declared the islands a reserve.

Carter Bequest.—The Vice-president, Mr Aston, read an opinion from Mr C. H. Treadwell on the possibility of utilising the Carter Bequest or part of it. Following on the reading of the opinion, Mr Eliott moved: "That the letter of opinion from Mr C. H. Treadwell, Solicitor, re Carter Bequest be accepted and adopted as the policy of the Society regarding the administration of the Fund. That this resolution and a copy of the Solicitor's opinion be forwarded to the Trustees of the Fund and to the Wellington City Council."

After some discussion, the President put Mr Eliott's motion, which was carried, Dr Marsden, Dr Kidson, and Professor Kirk dissenting. The opinion is as follows:—

The New Zealand Institute,
Wellington, C.1.

Re Astronomical Observatory.

Mr Charles Rooking Carter, formerly of Wellington, made his Will on the sixth day of June, 1896, and I am asked to give an opinion on a section of that Will.

The Will was duly proved, and I understand that two members of the Institute are trustees of this particular part of Mr Carter's Will, and accumulations of the Fund are vested in their names. The part of the Will to which I refer, and on which I am asked to give an opinion, is this:—

> "And as to all the residue and remainder (if any) of the said net proceeds of the sale, conversion, and getting-in of my estate as aforesaid, my trustee shall transfer the same to the Governors for the time being of the New Zealand Institute at Wellington, to form the nucleus of a fund for the erection in or near Wellington aforesaid, and the endowment of a professor and staff, of an astronomic observatory fitted with telescope and other suitable instruments for the public use and benefit of the Colony, and in the hope that such fund may be augmented by gifts from private donors, and that the observatory may be subsidised by the Colonial Government; and without imposing any duty or obligation in regard thereto, I would indicate my wish that the telescope may be obtained from the factory of Sir H. Grubb, in Dublin, Ireland."

The question is what those gentlemen in whom as Governors of the New Zealand Institute the fund is vested ought to do to carry out the trusts of the provision in question. It will be observed that the testator's intention was

that the fund should be transferred to the Governors of the Institute "to form the nucleus of a fund for the erection in or near Wellington aforesaid, and the endowment of a professor and staff, of an astronomic observatory fitted with telescope and other suitable instruments for the public use and benefit of the Colony." These are the words of the bequest on which the whole question turns. The principle upon which the whole question turns is as to the duty of those trustees with reference to the application of the fund. Originally the amount was approximately £2200, and the accumulations of interest up to the present time have brought the fund up to about £9000.

The real question is as to the method in which the intention of the testator should be carried out. This is a charitable trust, and, accordingly, there is no objection under the rules as to perpetuity to the fund being accumulated for an indefinite period.

It is suggested on the part of some of the Governors of the Institute that, inasmuch as the fund has now accumulated to about £9000, that £9000 should be expended towards the object indicated by the testator, notwithstanding the fact that it is manifestly impossible that the expenditure of the £9000 would be sufficient to carry out the testator's object. The other members of the Board of Governors consider that the fund should be further accumulated and allowed to increase so that it will be sufficient to really carry out the testator's intention.

In my opinion, it is beyond dispute that it is the duty of the Governors in whom the fund is vested to continue to accumulate it until it has reached such a sum as will be sufficient for the purpose of carrying out the testator's intention. It is plain, in accordance with the information before me, that it is impossible to do that with the fund in its present state of accumulation. Accordingly, it is plainly the duty of the trustees to continue to hold the fund subject to the trusts of the testator's Will until the amount has arrived either by the accumulation of interest, or by that method and the addition of other donations to the fund from other sources, at such sum as will make the testator's intention capable of being carried out. To expend the existing accumulations in partly doing what the testator intended is plainly not right, and, indeed, would, in my opinion, be a breach of trust for which the trustees in whom the fund is vested would be responsible. It is difficult to see how it can be suggested that a partial expenditure of the accumulated fund in the method suggested could be in any way a carrying out of the testator's intention. As I have said before, the testator's intention is what governs, and the trustees would not be justified in proceeding with the erection of an observatory which is probably all that the existing fund would provide for, without also providing for the other part of the testator's intention. It was not the testator's intention to build a trumpery observatory of little or no practical use in some corner of the Dominion, when, as a matter of fact, the fund is intended to be the nucleus or commencement of an accumulated fund sufficiently large to carry out the whole of the testator's intention. On this question I have no doubt whatever, and I am quite unable to advise the expenditure of this fund in anything else than the erection of a complete observatory endowed with a professorship and staff and the necessary instruments in the way provided for by the testator's Will.

I may add that the testator intended the augmentation of his bequest by gifts from private donors. Accordingly, he intended that the fund should remain unexpended until either by the accumulations of interest or by gifts of this character there should be sufficient money available to carry out his object.

I understand it is suggested that "in or near Wellington" is not a suitable locality for the erection of an observatory. It is plain that the trustees of this fund would have no authority to expend this fund for the purpose designated by the testator unless it were within the locality indicated. If it is found eventually that no suitable spot can be designated in or near Wellington where such an observatory can be erected, then it would be necessary, in my opinion, to obtain the sanction of the Court, or legislation, to the erection of an observatory in that other locality.

The trustees, in my view, have no authority to select such a locality of their own motion.

(Signed) C. H. TREADWELL.

Wellington, 14th September, 1933.

Roll Call.—On resuming after the lunch adjournment, the roll was called, the attendance being the same as in the morning.

Earthquake Building Construction.—Members having had an opportunity to peruse the statement, it was resolved on the motion of Dr Kidson that the statement drawn up be adopted and signed by the President, and that copies be circulated. On the motion of Dr Farr, it was resolved that an advance copy be forwarded to the Prime Minister. It was suggested that the statement be circulated to municipalities.

Hutton Grants.—On the recommendation of the Standing Committee, the following applications for grants from the Hutton Fund were approved:—

Mr L. C. King, £25 for geological research in the Marlborough District.

Messrs R. A. Falla and A. W. B. Powell, £40 for research on the molluscan and bird fauna of the Sub-Antarctic Islands of New Zealand.

Mr W. R. B. Oliver, £50 for assistance in publishing a monograph on the genus *Coprosma.*

It was recommended that the Standing Committee next year recommend an application from Dr Marshall for £25 for apparatus for measuring microscopic crystals.

An application from Mr K. M. Rudall for permission to transfer the balance of his grant for work on the Little Barrier Island to work on the Tararua and Ruahine Ranges was referred to the Standing Committee with power to act.

Levy Vol. 64.—On the motion of Mr Eliott, it was resolved that the levy on Volume 64 be 5s.

Report of Honorary Editor.

At the time when I was appointed Honorary Editor of the Transactions of the New Zealand Institute, arrangements had already been made for the publication of the final part of Volume 63, and the proofs had been revised. There were several papers on hand, and a few of these were ready for publication.

Most of the proofs for Volume 64, Part 1, are now in the page form, and that Part will shortly be published.

The papers for Part 2 of the same volume have been sent to the printer.

Some of the papers that are submitted for publication are of great length. It is impossible to accept some of them for that reason. Authors must, at the present time, reduce their papers as much as possible without omission of important matter. One paper is being published in four parts because of its great length. It is questionable whether this practice should be continued.

P. Marshall,
Honorary Editor.

Dr Marshall read his report and emphasised the necessity for reducing the length of papers submitted for the Transactions. He referred to the great help given him by the Associate-Editor, Dr Turner. He moved the adoption of the report, seconded by Dr Turner, and carried. On the motion of Dr Marsden, seconded by Mr Oliver, it was resolved: "That the Editor be supported in the stringent editing of papers for the Transactions with a view to greater economy and efficiency. Unless under very exceptional circumstances, no paper shall exceed 20 pages."

On the motion of Dr Marsden, seconded by Dr Farr, it was resolved that the President's address, or the major portion of it, be printed in the Transactions.

Reports of Research Grantees.

Mr B. C. Aston, who in 1928 took over a balance of £9 16s 7d from Dr Malcolm for research on pukateine, reported on the 19th April, 1934, that the research on pukateine has been continued by Professor Barger and his assistants, the third alkaloid in the bark, lauropukine, being the immediate subject of investigation, but no reports have been received during the year. On the physiological side of the investigation a small quantity of the pukateine hydrochloride has been supplied to Dr Fogg, demonstrator of Physiology at the Otago Medical School, at his request. No further report has been received from him. There is an unexpended balance of £7 12s 11d.

Mr G. Brittin, who in 1919 was granted £20 for investigation of fruit tree diseases, reported on the 21st April, 1934, that the work of the past year consisted in observing the effects of weather conditions on the prevalence of brown rot. Some interesting comparative results were obtained. This season all the trees showed a heavy setting of buds, with promise of a heavy crop to follow. However, just before the flowers were fully opened, small birds completely stripped the trees. Such an occurrence has never taken place before; several other orchards were similarly affected. No money was expended.

Mr A. E. Brookes, who in 1928 was granted £40 for a research on the coleoptera of the islands off the Auckland coast, reported on the 30th March that most of the time during the year was occupied in examining specimens considered to be new or doubtful species, and some of the new species have been described. Still more work of this nature remains to be done. There is an unexpended balance of £1 16s.

Mr J. W. Calder, who in 1930 was granted £30 for research in the vegetation of Arthur's Pass, reported on the 19th April that there is little further to report. An account summarising the main changes in the vegetation was published by Dr Cockayne and himself in the Journal of Ecology. He is continuing a more detailed investigation of particular areas, establishing, plotting, and locating vegetation quadrats. These are being marked out with iron pegs, and directions for finding these pegs from permanent landmarks are prepared. The grant is exhausted, so no expenditure has been incurred.

Miss L. Cranwell, who in 1930 was granted £20 for an ecological survey of the marine algae of the West Coast near Auckland, reported on the 30th April that field work has been continued on the lines indicated in her previous report. Unfortunately, extensive sanding-up has occurred in the Anawhata bays specially chosen for the study of summer ephemerals, so this branch of the work has received a setback. Miss Cranwell hopes to complete a general paper before the spring. Comparative notes were made on Taranga and Poor Knights Islands in November. Expenses during the year amounted to £3 0s 7d, leaving an unexpended balance of £2 19s 4d.

Dr H. G. Cunningham, who in 1929 was granted £25 for a mycological survey of the Tongariro National Park, reported on the 26th April that during Easter, 1934, five days were spent collecting fungi on North Tongariro, 17 collections being secured. No expenses were incurred, and the unexpended balance remains at £18.

Dr C. C. Farr, who in 1927 was granted for research on helium an additional amount of £150, and who still has a balance of £44 9s 4d remaining to his credit, reported on the 19th April that although no work was done on this research during the year, the apparatus is all set up and ready for an investigation whenever helium is obtained, and he should like the balance to remain at present.

Miss E. M. Heine, who in 1930 was granted £15 for the study of the pollination of New Zealand plants, reported on the 23rd April that she is still waiting for the completion of identification of the insects effecting pollination which the Dominion Museum entomologist has been naming for her. These will be completed in a short time, and then a full account of the results will be published. The whole of the grant has been expended.

Dr J. K. H. Inglis, who between 1923 and 1930 was granted £125 for research on the essential oils of native plants, reported on the 25th April that no further work had been done during the year, but he hopes to resume next year, when the unexpended balance of £3 13s will be used.

Mr R. M. Laing, who in 1929 was granted £25 for research on marine algae, reported on the 24th April that a third of his papers on *Gigartina* is progressing and much other work is in hand. The grant is exhausted.

Mr A. W. B. Powell, who in 1925 was granted £50 for an investigation of molluscan fauna of the Manakau Harbour, and also for working up the results of a number of shallow water dredgings from off the New Zealand coast, reported on the 19th April that during last season little field work was done, but the material dredged during the previous season was completely sorted, and samples of the bottom were mechanically graded, and the results tabulated and prepared for publication. With the aid of the microscope purchased by means of the grant, six papers have been prepared for publication. There is an unexpended balance of 10s 5d.

Mr G. H. Uttley, who in 1928 was granted £35 for research on New Zealand Bryozoa, reported on the 27th April that the work is still proceeding, and comparison with Australian forms is now being made by exchange of specimens. No further expense has been incurred.

The Waitemata Harbour Survey, which in 1925 was granted £65 and in 1932 an additional sum of £25 as a Hutton grant, reported on the 19th April that a large series of dredge stations has been made during the year, and several new areas of the harbour have been investigated. Seventy dredging stations have been selected for mechanical grading, which means the tabulation of 560 samples, all of which have been dried, weighed, and the results made the basis of numerous graphs. A paper prepared for the Committee by Mr W. K. Hounsell has been submitted for publication in the Transactions. There is an unexpended balance of £14 17s 9d.

Hutton Grantees.

Mr L. C. King in 1932 was granted £20 to enable him to conduct a field study of the tertiary rocks in the Awatere Valley. He reported that with an assistant ten and a-half weeks were spent during the summer 1932-33. In this period 250 square miles of country were mapped geologically. An account of the work is almost ready for publication. It shows that the district consists of a number of separate fault-bounded earth blocks which have been subjected to compression and some of which have been strongly rotated. The tertiary rocks have been divided into three series: Medway Series of Awamoan age, Upton Series of Taranakian age, and Starborough Series of Waitotaran age. During the year Mr King proposes to return to the district and prepare a paper on the physiography of the area accompanied by a comprehensive block diagram. This will complete the work.

Mr K. M. Rudall, who in 1933 was granted £5 for zoological research on Little Barrier Island, reported on the 29th March that two weeks were spent on the Island in January, 1933. Collections were made of the land mollusca, earthworms, and flatworms. The two last groups have been stored for reference, while an intensive study of the first group only is intended at present. Fresh water mollusca were also collected. Mr Rudall supplies a long list of species found. With the completion of the list of species from Little Barrier some interesting conclusions should be forthcoming concerning the probable relationships with the mainland. Total expense amounted to £1 15s 6d.

On the motion of Professor Speight, seconded by Mr Hudson, this report was adopted.

Tongariro National Park Board, 1933-34.

Report of Representative.

I have pleasure in reporting that in the annual report of the Park Board for the year ending 31st March, 1933, there has been inserted three brief reports on the wild life of the Park, the insects being dealt with by Mr G. V. Hudson, the birds by Mr W. R. B. Oliver, and the fishes by Mr W. J. Phillips. The printed report is before this Council for inspection.

An important feature of the report, which should be highly satisfactory to the Institute, is the statement of the Chairman of the Board, Mr W. Robertson, as follows:—

> "Evidence is accumulating to show that some effective steps will have to be taken to counter the detrimental effects of housing animals within the parks. Some thousands of goats have been destroyed in the Egmont Park; but the total extermination of these animals cannot be effected without further funds with which to carry on the work. At Arthur Pass deer and chamois are damaging the mountain flora, and deer are becoming established in the forest on the western portion of Tongariro Park. Red deer are fairly numerous in portions of the Sounds National Park, while there is need for investigation into the effects of moose and wapiti in that region. The Department is convinced that deer and other plant-eating animals must be recognised and dealt with purely as a menace to our national parks and reserves, and not as a means of providing sport for a few persons or as an attraction for tourists. The welfare of the native flora must be the first consideration at all times"

It is regrettable that in spite of this announcement regarding the importance of conserving the native flora, the necessity of considering the native fauna has apparently been disregarded, and the introduction of trout fry into the stream in the Park has been permitted by a majority vote of the full Board.

A full meeting of the Park Board, which was attended by your representative, was held in the Chateau on 26th January, which gave members of the Board an opportunity to inspect the considerable improvements effected at the Chateau under the management of the Tourist Department. The golf links have been considerably improved, and are a great feature of attraction It is satisfactory to record that during the past year the Board has taken up a strong position in dealing with unauthorised cutting of timber in the Park and the eradication of certain exotic plants, lupins, which are spreading into the Park, and that the Board is taking steps to allow reliable persons to shoot deer within the boundaries of the Park in order to keep these animals in check as far as possible. A new decision of the Board is that instructions and directions for dealing with tussock, scrub, and bush fires on lines suggested by Mr E. Phillips-Turner shall be posted up along the road frontages of the Park.

B. C. Aston,
Representative on Park Board

Mr Aston read and moved the adoption of his report as representative on the Park Board. He stated that he had protested against the introduction of trout into the Park streams, but his protest had been overruled. The heather was increasing so slowly that it was negligible. It was not competing with the native flora to any great extent. In reply to a question by Mr Pycroft as to whether a firebelt could be cut, Mr Aston replied that the area was too large for such an undertaking. Professor Kirk seconded the adoption of the report; he considered that the Society should support its representative in his protest regarding the introduction of trout fry into the streams. The report was adopted.

Arthur Pass National Park, 1933-34.

Report of Representative.

The operations of the Board controlling this Park have been hampered a good deal during the year owing to want of funds. The revenue accruing from rents, etc., has been too small to meet ordinary expenditure, and there has been a serious drain on the capital sum set aside for the development of the Park when it was established.

Plans have been completed for the formation of an Alpine Garden at Arthur Pass, but these have been held up owing to shortage of funds. It is to be hoped, however, that the project will be advanced during the coming year.

Tracks have been constructed to give access to various points of interest, and to enable the Park to be thoroughly controlled by rangers. As much protection as possible has been given to the native fauna and flora, and the latter will benefit materially as a result of the destruction of deer and chamois which has been carried out by the Department of Internal Affairs at the instigation and with the financial help of the Waimakariri Trust. I should like to give my personal testimony to the thoroughness with which this work has been done by the officers of the Department.

R. SPEIGHT,
Representative on Board.

Professor Speight moved the adoption of his report as representative on the Arthur's Pass National Park Board. He commented on the deer menace in the Park, stating that this was being controlled. Chamois and thar could be seen in herds of about twenty; these had not the commercial value when killed which deer had. In regard to the Alpine Garden commenced in the Park, completion of this had been delayed owing to lack of funds and a slight disagreement with the Unemployment Board. Dr Marsden seconded the adoption of the report, which was carried.

WARD ISLAND DOMAIN BOARD.

Report of Representative.

The annual meeting of the Ward Island Domain Board was held on May 25th, 1933. The report for 1932 was presented, and it was decided to make arrangements for further visits to the Island for the purpose of making a path to the top and planting trees. Through the courtesy of Mr A. Holmes, who made his launch available, members of the Board visited the island on August 8th, 1933. About 75 trees were planted, including 50 provided by the Wellington City Council.

Two members of the Museum staff, Miss Heine and Miss Plank, accompanied the party and assisted in investigating the native plants and insects found on the island.

W. R. B. OLIVER,
Representative on Board.

Mr Oliver, representative on the Ward Island Domain Board, moved the adoption of his report, seconded by Mr Hudson, and adopted.

N.Z. INSTITUTE OF HORTICULTURE.

Report of Representative.

The work of the New Zealand Institute of Horticulture has been carried on during the year along the same lines as in previous years, and monthly meetings of the Executive Council have been held and have been attended by your representative.

Financial considerations have dictated that the Journal of the Institute, which is only published half-yearly in March and September, should be supplemented by the publication of a mimeographed news letter and distributed between the above dates, which will keep the members in touch with current doings in the local world of horticulture.

Loder Cup.—The conditions attending the award of the Loder Cup are, in the opinion of your representative, far from satisfactory, and the Executive has asked the Minister to re-establish the Loder Cup Committee, with a view to determine the existing conditions. The Hon. the Minister of Agriculture has consented to this course, and has appointed a committee consisting largely of the original committee.

Arbor Day.—The matter of re-instituting Arbor Day in New Zealand has been discussed, and it is hoped that it will be possible at no distant date to re-establish the observance of this day throughout the Dominion.

Horticultural Information.—A committee, of which your representative is a member, was set up to consider and report on the preservation of seedsmen's and nurserymen's catalogues and other horticultural literature. As a result of the committee's deliberations, a report was furnished to the Institute, and a scheme was adopted whereby the Turnbull Library will receive as many individual catalogues, etc., issued in the past years as possible, and in future will receive from all New Zealand nurserymen copies of their catalogues. At the same time, a copy will be filed by the Institute of Horticulture. By this means it is hoped to endeavour to remove the existing ground for reproach that there is at present no readily available means by which the history of the horticultural development in the Dominion can be studied.

The Institute is taking an active part in making representations with regard to the preservation of the various examples of typical New Zealand forest life. It is also corresponding with the Commissioner of State Forests on the protection of forests from plant-eating animals.

The Institute is also endeavouring to obtain the consent of those owners of representative gardens to enable the public to visit them under certain conditions. The Institute has lent its patronage to the usual shows during the year, especially to the National Flower Show, held at Palmerston North in January, 1934.

B. C. Aston,
Representative on Council.

Mr Aston, representative on the New Zealand Institute of Horticulture, moved the adoption of his report, which was seconded by Professor Segar and adopted.

Great Barrier Reef Committee

Report of Representative.

The Committee met twice during the year 1933. H.M.A.S. Moresby was recommissioned during the year, and was to carry out hydrographic survey work on the reef. Research work on the reef is to be continued by Mr F. W. Moorhouse, who was appointed part-time Field Investigator for the Committee.

The protection of the fauna and flora received attention from time to time. Certain islands have been added to the list of sanctuaries, the taking of guano has been prohibited on some of the islands, and it was resolved to take steps to mitigate the wanton destruction of plants and animals by tourists.

Volume IV of the Committee's Report was issued during the year. It contains a detailed account of the life history of the green turtle.

The balance in hand on September 13, 1933, was £2238 1s 2d (including £1500 invested).

W. R. B. Oliver,
Representative on Committee.

Mr Oliver, representative on the Great Barrier Reef Committee, moved the adoption of his report, which was seconded by Mr Hudson and carried.

New Zealand Polar Year Committee.

Report for the Year ending 31st March, 1934.

The Quick-Run Magnetographs received from the International Polar Year Commission have been in operation at Amberley throughout the year, under the charge of Mr H. F. Skey, Director of the Christchurch Magnetic Observatory. Mr Skey was authorised to employ assistance in the preparation, tabulation, etc., of the records, and excellent progress has been made. The ordinary magnetograph records secured at Amberley also are being copied. The copies, together with the originals from the Quick-Run set, will be forwarded to the Polar Year Commission at Copenhagen. All records are to be collected at the headquarters of the organisation, where their discussion will be entrusted to specially-appointed experts, and where, also, they will be available for other investigators who wish to study them.

The Polar Year was magnetically a quiet period, and Mr Skey wishes to continue the working of the Quick-Run Magnetographs in the hope of recording some intense magnetic storms. It is probable that numbers of other observatories will also keep their instruments in operation for a further period.

The programme of extra meteorological observations at Wellington and Christchurch has been completed.

The authorities concerned consider that the Polar Year scheme has been very successfully carried out. An immense amount of valuable data has been collected, and the International Commission is proceeding vigorously with the publication and discussion. Numbers of researches are already under way, but the President anticipates that these matters will keep the Commission fully occupied for another five years.

Magnetograph Fund.

Statement of Receipts and Expenditure for Year ending 31st March, 1934.

Receipts.	£	s.	d.	Expenditure.	£	s.	d.
To Balance in Post Office Savings Bank ..	148	9	6	By Balance forward	152	14	10
Interest in 1932-33 Financial Year	3	19	7				
Cash ..	0	5	9				
	£152	14	10		£152	14	10

Interest to the amount of £4 11s 2d has accrued during the year ending 31st March, 1934.

EDWARD KIDSON, Hon. Secretary.

Approved.

G. SHIRTCLIFFE, Chairman.

Audited and found correct.

E. J. ARCHIBALD, Accountant.

Wellington, 30th April, 1934.

Note added: Since the end of the financial year, expenditure to the amount of £109 7s 11d has been incurred. It is anticipated that the remaining funds will be absorbed during the current year.

Dr Kidson, secretary of the Polar Year Committee, moved the adoption of his report, which was seconded by Dr Marsden and carried.

National Art Gallery and Dominion Museum.

Report by Vice-president.

During the year ending 31st March, 1934, five meetings of the Board of Trustees have been held, and these were attended by your representatives, the President's deputy (Professor Kirk or by Dr Marshall) and the Vice-president; also by Mr Oliver, a member of this Council.

A matter for congratulation is that the Hon. the Minister of Internal Affairs (Mr Young) was able to attend and preside over most of the meetings.

Building.—The main work of the year took place in connection with the erection of the main building, which had been decided upon last year. The building operations have gone steadily forward according to schedule; Putaruru vitric tuff is the only stone being used in the construction, and it has continued to give the same satisfaction as it has done in the completed Carillon building. At the end of the business year, 31st March, 1934, the erection of the building was well advanced, and the arrangements for the laying of the foundation stone had been completed. It is now possible to see from the lay-out the Museum galleries.

Committee of Control.—Messrs Fraser, Aston, and Oliver were appointed a sub-committee to look into the matter of an appointment of a committee to control the Museum as provided by the Act, and to report later to the Board, but so far no meeting of this committee has been held.

Finance.—The collection of outstanding subscriptions has proceeded satisfactorily, and with the assurance of the Government subsidy the finances may now be described as being in a sound condition, and the completion of the building scheme is assured.

An amending Act to the National Art Gallery and Dominion Museum Act was introduced and passed by Parliament last session; this provided for the appointment, when necessary, of an acting-chairman to the Board, as well as permitting the Wellington City Council to have an additional representative on the Board.

It is interesting to note that the Museums Journal (England) of December, 1933, contained a description of the history and organisation of the National Art Gallery and Dominion Museum (Wellington), and devoted space to the reproduction of plans of the buildings. The same journal also stated that the Carnegie Corporation of New York has allocated 50,000 dollars for the development of Museum work in New Zealand, to be administered by a local committee.

B. C. ASTON,
Vice-president.

Mr Aston, vice-president, moved the adoption of his report on the Board of Trustees, seconded by Professor Segar, and carried.

Observatories' Committee.—Dr Farr reported that no meetings of the Committee had been held during the year. The position in regard to the Apia Observatory was not very satisfactory—he considered that more of the burden of the upkeep of the Observatory should be borne by New Zealand, and that it should fall less on outside countries.

Notices of Motion were then dealt with as follows:—

Scientific Education.—Professor Kirk moved, Mr Pycroft seconded, and it was carried: "That the Royal Society of New Zealand much regrets that the Government has found it necessary to make further economies at the expense of scientific education."

Lord Rutherford's Portrait.—Dr Farr moved, Dr Kidson seconded, and it was carried: "That the Royal Society of New Zealand again affirms its interest in the proposal of His Excellency the Governor-General that a copy of Mr Oswald Birley's painting of Lord Rutherford, of Nelson, be procured for the Dominion Museum and National Art Gallery."

Medals.—Dr Farr moved, Professor Kirk seconded, and it was carried: "That only under the most exceptional circumstances should there be two awards of the same medal in one year."

Scientific Libraries.—Dr Marsden moved, Dr Kidson seconded, and it was carried: "That the Library Committee be asked to collaborate with the officer of the Carnegie Corporation at present in New Zealand with a view to furthering an arrangement for better scientific libraries and co-ordination thereof."

Polar Medals.—Mr Pycroft moved, Mr Oliver seconded, and it was carried: "That this Council congratulates Mr R. A. Falla, M.A., of Auckland, and Mr R. G. Simmers, M.Sc., of Wellington, members of the British and New Zealand Antarctic Research Expedition, who have been awarded the Polar Medal by His Majesty."

A. and N.Z. Assoc. Adv. Science.—In regard to the proposed meeting of the Association in Auckland in 1937, Professor Segar stated that Mr Archey hoped to visit the Melbourne meeting next year

in order that he might gain an insight into the running of the meeting and to ascertain what expense is involved in such a meeting.

Science Congress.—The practicability of holding a Science Congress in the near future was discussed. It was pointed out by the Vice-president that neither Hawke's Bay nor Nelson was in a position to hold a Congress. Auckland had organised the last one held, and it was now undertaking the A. and N.Z. A.A.S. meeting in 1937. It was Wellington's turn. Dr Turner thought that the Otago Institute might be willing to hold the Congress unless there was expense involved. Finally, on the motion of Mr Pycroft, seconded by Dr Kidson, it was resolved that the possibility of holding a Science Congress in 1935 or 1936 be referred to the member bodies, and that the Standing Committee be given power to act.

Reference List of Scientific Periodicals.—On the motion of Dr Marsden, seconded by Dr Kidson, it was resolved that the Library Committee be asked to endeavour to bring out the revised List of Scientific Periodicals during the year, and that the arrangement be along the lines adopted in the British Museum catalogues.

Election of Officers.—The election of officers resulted as follows: President, Professor R. Speight (re-elected); Vice-president, Mr B. C. Aston (re-elected); Hon. Treasurer, Mr M. A. Eliott (re-elected); Hon. Editor, Dr P. Marshall; Associate Hon. Editor, Dr F. J. Turner; Hon. Librarian, Professor H. B. Kirk; Co-opted Member, Dr P. Marshall (re-elected); Managers' Trust Accounts, Messrs M. A. Eliott and B. C. Aston (re-elected); Hon. Returning Officer, Professor H. W. Segar (re-elected); Representative Tongariro National Park Board, Mr B. C. Aston (re-elected); New Zealand Institute of Horticulture, Mr B. C. Aston (re-elected); Great Barrier Reef Committee, Mr W. R. B. Oliver (re-elected); Observatories' Committee, Dr C. C. Farr and Professor P. W. Burbidge.

Election of Committees:—

Research Grants Committee: Dr Hilgendorf, Professor Speight, Dr Benham, Dr Farr, and Mr C. E. Foweraker (all re-elected).

Hector Award Committee: Mr G. V. Hudson (convener), Dr Marwick, Professor Agar (Melbourne), Professor Harvey-Johnstone (Adelaide University).

Hutton Award Committee: Dr Marshall (convener), Dr Holloway, Professor Bartrum, and Dr Benham.

Hamilton Award Committee: Dr Marshall (convener), Dr Benham, and Dr Holloway.

Finance Committee: Messrs Eliott, Aston, Drs Marsden and Kidson.

Sidey Summer-time Award Committee: Dr Marsden (convener), Dr Malcolm, and Lord Rutherford.

Library Committee: Professor Kirk, Dr Cotton, Dr Kidson, and Mr Oliver.

Regulations Committee: Mr B. C. Aston, Dr Marshall, Dr Marsden, Dr Kidson, and Professor Shelley.

Annual Meeting, 1935.—To be held in May, actual date to be fixed by the Standing Committee.

Votes of Thanks.—Hearty votes of thanks were accorded to the President, Professor Speight; the Press; Victoria University College; the Secretary, Miss Wood; the Honorary Officers.

Confirmed 29th May, 1934.

(Signed) B. C. ASTON, Chairman.

To mark the inauguration of the Royal Society of New Zealand, the Council of the Royal Society was entertained by the Wellington Philosophical Society at a conversazione held on Wednesday evening, 16th May, 1934, in the Conference Hall of the Dominion Farmers' Building.

The President of the Wellington Philosophical Society, Dr Henderson, welcomed the members of the Council, the Rt. Hon. the Prime Minister, and others who were present, and then asked the President of the Royal Society of New Zealand, Professor Speight, to take the chair. Professor Speight read a message from His Excellency the Governor-General, which was warmly applauded.

Professor Speight then delivered his presidential address.

At the conclusion of the address, Dr Cockayne, in moving a very hearty vote of thanks to Professor Speight for his address, made some interesting remarks on the link between the Royal Society of London and New Zealand, and said he was sure the Royal Society of London would wish him to convey its congratulations and best wishes on the occasion of the inauguration of the Royal Society of New Zealand.

The Prime Minister, the Rt. Hon. G. W. Forbes, then delivered a short address, in the course of which he expressed his regret that the Society's grant had had to be cut down. Dr Farr, in thanking the Prime Minister for his address, remarked that the Society hoped that before long it would have the pleasure of thanking him again for the restoration of the grant.

The President then presented the special Sidey Summer-time medal and prize to Mr G. V. Hudson for his pioneer work in daylight saving.

With supper, a very successful evening was brought to a conclusion.

The following day the morning session was devoted to interesting lectures given by the following:—Dr F. J. Turner spoke on the scope of geological research in New Zealand. Professor Burbidge spoke on recent developments in the science of physics. Dr L. Cockayne gave some observations on biology in New Zealand.

In the afternoon members were taken to the Otari Open-air Museum and then on to the Meteorological and Dominion Observatories, after which they were entertained at afternoon tea by the Wellington Philosophical Society.

The cordial thanks and appreciation of the Royal Society of New Zealand are due to the Wellington Philosophical Society for the excellent arrangements carried out by it for the inaugural meeting of the Society.

GOVERNOR-GENERAL'S ADDRESS

ADDRESS FORWARDED BY HIS EXCELLENCY THE GOVERNOR-GENERAL, LORD BLEDISLOE, TO THE INAUGURAL MEETING OF THE COUNCIL OF THE ROYAL SOCIETY OF NEW ZEALAND.

TO THE COUNCIL OF THE ROYAL SOCIETY OF NEW ZEALAND, ASSEMBLED AT WELLINGTON, 16TH MAY, 1934.

Gentlemen,

I am much disappointed that public engagements in the Auckland District will prevent my attending the inaugural meeting of the Council of "The Royal Society of New Zealand" (hitherto called "The New Zealand Institute), of which I am privileged to be the Honorary Patron, and partaking with its members of the hospitality so kindly accorded to them by the Wellington Philosophical Society. During my happy sojourn in New Zealand for the last four years no vicarious duty as the King's representative has caused me more sincere satisfaction than the intimation of His Majesty's approval of the new designation of the Dominion's chief organisation for the promotion of science within its borders and the utilisation for the enrichment and happiness of mankind of its multiform intellectual output. The New Zealand Institute was founded in 1867, and in this, the sixty-seventh year of its useful existence, it becomes revitalised under a title more befitting its status and its record of worthy achievement. No Society within the Empire has during the last half century more richly earned the praenomen of "Royal." Its printed Transactions, as well as its Natural Science Bulletins, have been a material contribution to the world's storehouse of scientific knowledge. Its Fellowship (held by 48 of the Dominion's most prominent scientists) is not lightly conferred. It is evidence of scientific achievement of a high order, and is so regarded in other parts of the world. It has numbered within its ranks, and still numbers, men of outstanding ability, industry, and genius, who, in various branches of scientific investigation, have conferred untold benefits upon their fellow-countrymen and upon that wider fraternity of searchers after accurate knowledge among whom international frontiers present no barrier of sympathetic intercourse and co-operation. It can claim, inter alios, as one of its compatriot members Ernest Lord Rutherford, the leading scientist of the British Empire, if not of the world. Science is, as I have indicated, a consolidating and harmonising influence in a world racked by international controversies and disrupted, at least temporarily, by fissiparous economic nationalism. Science is often blamed by a myopic and ungrateful public for the world's economic maladjustment and malaise, oblivious of, or deliberately blind to, the fact that Science has proved the chief source and mainspring of man's material prosperity in ever-increasing

intensity with successive decades of its application to man's changing and exacting requirements. If the application of science to human industrial operations has created a surplus of productive wealth with resulting human impoverishment, the fault lies, not with the scientist, but with the economists, the financiers, the industrialists, and, above all, the statesmen of the world, who, in consequence of ignoring, and failing to utilise to the full, the aid of Science in solving the world's social and economic problems, are now battling with destitution in a world of superfluity, and by fostering national economic isolation are rendering precarious the foundations of world peace. To starve knowledge (and especially that clearly ascertained and systematised knowledge which we designate Science) or to stint it of its due reward is to court national disaster. If Science, in the inevitable evolution of human genius, has contributed to economic adversity, it is because it has been applied in part only to the solution of human problems, and certain it is that only by the further application of Science in all its ramifications and by a far more generous and enlightened recognition of its beneficent potentialities by the world's rulers will effective remedies for current human disorders be found. It is for these reasons, and also because, in a geographical sphere of unsurpassed natural loveliness and hitherto undisclosed and intriguing natural secrets, scientific knowledge is providing its mentally alert inhabitants of all classes with a fuller and more radiant life, that I offer my most sincere patronal salutations and congratulations to the Royal Society of New Zealand, which has for considerably over half a century, under its humble name of the New Zealand Institute, acted as a beacon of intellectual enlightenment in this isolated land of immeasurable opportunities for industrial and cultural expansion, and my earnest hope that under its new appellation it may not only augment its already high prestige, but enjoy to an ever-increasing extent the confidence and respect of the community at large.

Vale et salve.

Believe me, Gentlemen, to be always your most sincere well-wisher and colleague,

BLEDISLOE,
Governor-General.

Government House,
Auckland.
14th May, 1934.

PRESIDENTIAL ADDRESS

Inaugural Address delivered May 16th, 1934, by Professor R. Speight, M.Sc., F.G.S.:—

The President, Wellington Philosophical Society, the Right Honorable the Prime Minister, Ladies and Gentlemen,—

In this address on the occasion of the establishment of the Royal Society of New Zealand, I propose to give a brief summary of the development of scientific research in New Zealand from the earliest times up till the present. The period under review is a long one, practically 160 years, for in 1768 Cook made this land really known to the world. From his arrival till the foundation of the New Zealand Institute, nearly 100 years passed, and all through this period the mode of approach to the scientific problems presented by the country was practically the same, viz., the visits by expeditions from Europe and America, the amassing of collections, chiefly botanical, to a less extent zoological, and to a minor degree geological, and their description in monographs of imposing dimensions by experts in various branches, the publications usually being at the expense of the government of the land where the expedition originated. The authors were in many cases but little acquainted with the environment of the organisms they described. The stimulating influence of being associated with a new land did not operate therefore to any degree, except in the case of those men of science who actually accompanied the expeditions, and even in their case the stay was relatively brief.

Cook was primarily a navigator, and his own particular sphere was coastal survey, and the making of astronomical and magnetic observations. He was, for that reason, the first physicist, or rather geophysicist, associated with New Zealand science. One must remember, too, that he was the first Fellow of the Royal Society who had the honour conferred on him for work in New Zealand: it was not for his survey work, however, but because he discovered a method for the mitigation of the ravages of scurvy.

Although Cook's work in the directions indicated was most notable, the scientific results of his expeditions, apart from the geographical and ethnological, were those associated with the natural history of the new land. He was himself a close and accurate observer of natural phenomena and of the customs and habits of native races, and he had with him a scientific staff of naturalists especially strong on the botanical side: but they were concerned with the making of collections for the enrichment of herbaria and gardens, and with systematic description rather than the study of plants in their natural surroundings. The time of plant ecology had not arrived.

Other expeditions, fitted out in the northern hemisphere, followed close on the heels of Cook. The French sent various ships. Lieutenant D'Urville was on the first, no mean botanist himself, and associated with him were the naturalists Lesson, a botanist, and Quoy and Gaimard, zoologists, all names to be connected with the descriptions of new plants and animals. Subsequent to his first expedition,

D'Urville came as admiral in command, and collections, especially of plants, molluscs, crabs, insects, and birds, were made by the staffs of all the ships.

The Americans sent an expedition headed by Admiral Wilkes in 1840, which made collections of birds, shells, and crustacea. Then Great Britain also sent, in 1841, the ships *Erebus* and *Terror*, under Sir James Clark Ross, and extensive collections of animals were made as well as of plants, for included in the staff was Joseph Hooker, afterwards Sir Joseph Hooker, who really laid the foundation of the systematic botany of New Zealand. Later on we have the visit of the *Novara*, sent by the Emperor of Austria in 1859, with a distinguished personnel in which was included Ferdinand von Hochstetter, the first geologist of repute to visit New Zealand and examine the country. Its physical features had already attracted attention, for we have numerous references to it in the later editions of Charles Lyell's "Principles of Geology."

Before 1867 there were other expeditions of relatively minor importance, but subsequent to this date, in the year 1874, there were brief visits from the *Challenger*, and from the French expedition to Campbell Island to observe the Transit of Venus.

Visits were paid by other men of note, e.g., by Charles Darwin, who came to the Bay of Islands in the *Beagle* in the year 1836, by Dr Lyall in the *Acheron*, and Dieffenbach included in his travels in the year 1840 a visit to the Chatham Islands. Any accounts they gave were based on a stay of a few weeks, or months at most, and were largely systematic and not related in any close way to the land itself, although most appreciative references were made to the beauty of the forest, the majesty of the mountains, and the sterling character of the Native inhabitants. Darwin was an exception. New Zealand did not impress him except unfavourably, for he says in his Journal: "I believe we were all glad to leave New Zealand. It is not a pleasant place. Among the Natives there is absent that charming simplicity which is found at Tahiti; and the greater part of the English are the very refuse of society. Neither is the country itself attractive. I look back but to one bright spot, and that is Waimate, with its Christian inhabitants."

But from about the year 1860 a great change took place, and the scientific work was carried out very largely by men who made the country their home, and to them we owe the eminence to which the distinctive New Zealand science has attained. It is strange that the first men of science who were attracted by the country were botanists, then zoologists, but the real basis of New Zealand science is due to men who were all primarily geologists—Hector, Haast, and Hutton. This may be only a coincidence, but geology was a science of late development and reached a stage in the early '60's when advance was rapid. The crude and fantastic theories of earlier date had been overthrown, men were going direct to nature for their inspiration, and no wonder a land like New Zealand, with its varied phenomena, was responsible for an intelligent appreciation of the different forces which had fashioned it. In some departments these men were

pioneers. Hector was the first to explain the development of over deepened fiords by the excavating powers of great valley glaciers. Haast, as a resident on the Canterbury Plains and intimately acquainted with the vagaries of the rivers overcharged with the waste from mountains higher in their basins, was thoroughly conversant with the factors controlling its deposition and the building up of river beds, and to him is to be credited the first use of the word "fan" in a scientific sense as applied to that form of deposit.

The new idea of the former extension of glaciers was creating keen interest and varied expression of opinion in the northern hemisphere, and both Haast and Hector added materially to the discussion in support of those who maintained their extension. This evidence coming from another hemisphere had a very important influence on the conclusions which were ultimately established. As is the case with pioneers in a new land in other spheres of action, these two men had to undertake varied work, and both were noted for the many-sidedness of their activities. In the case of Hector, this can be exemplified by the various subjects for which the medal associated with his name stands—botany, chemistry, ethnology, geology, physics, zoology—for in all these he attained some distinction. Haast, too, was a botanist, zoologist, and ethnologist, as well as being a geologist. But Hutton was the one of widest attainments, for in addition to his geology we owe much to his systematic work in many departments of zoology, notably conchology, entomology, and vertebrate zoology. He was, however, no mere systematist, but a close observer in the field, and he brought to bear on various problems of natural history a philosophic mode of approach which gave new interest to what had been previously isolated scientific facts. We know now that some of his reasoning was unsound, and his conclusions therefore invalid, yet he exercised in his time a very profound influence on New Zealand science, an influence frequently associated with those who make startling generalisations or enunciate apparent paradoxes, the very effort of disproving them materially advancing the cause of truth.

These men were jacks of all trades, and dare we say they were masters of none? For the age of specialists had not arrived, when the object is to know "more and more about less and less." Yet this failure to possess an accurate knowledge of a limited subject did give them a catholicity of outlook and a freedom of imagination which is of the greatest help in a pioneer, and not without advantage to a worker in a limited sphere of advanced research. These were the men who dominated the latter half of the century in New Zealand science. Haast died comparatively early after a full and vigorous life, but Hector and Hutton survived into the early years of this century, and I think we are greatly indebted to them for the high standing of the New Zealand Institute.

It must be remembered, too, that at this stage there were notable stirrings in the scientific world. Darwin published his "Origin of Species" in 1859, and Hutton was an ardent advocate of his theories,

and, in fact, he provided instances which Darwin used in his memorable work. And as early as 1862, just three years after the book appeared, in a Presidential Address to the Philosophical Institute of Canterbury, Haast maintained that it was "the great work of the age."

The first body in this country to which the name scientific can be given is the New Zealand Society established in Wellington very early in the history of the colony, viz., in 1851. Sir George Grey delivered an inaugural address, presided in person at its meetings, and helped it substantially by his lively interest. From this developed the Wellington Philosophical Society, so that it is in some measure the parent of the New Zealand Institute. It is appropriate, therefore, that the celebration of the establishment of the Royal Society of New Zealand is being conducted with its cordial support and under its direction.

The New Zealand Institute was formally established in 1867, over 60 years ago, by the New Zealand Institute Act, through the incorporation of various independent societies in Wellington and other parts of New Zealand, viz., the Wellington Philosophical Society, the Philosophical Institute of Canterbury, the Auckland Institute, and the Westland Naturalists and Acclimatisation Society. Three of these had a vigorous existence, but the last-named languished after a time and finally ceased to exist Soon after its formation, the Institute was strengthened by the addition of the Otago Institute, and there followed on the Hawke's Bay Philosophical Society, and societies centred on Wanganui, Nelson, and Palmerston North

On August 4th, 1868, the then Governor of the Colony, Sir George Ferguson Bowen, as the first President, delivered an inaugural address, in which he briefly described the steps leading up to its establishment, and then in an eloquent manner detailed the various branches of science which would come within the sphere of activity of the new Institute, and indicated the directions in which, in his opinion, they would probably develop. He mentioned the Geological Survey, then recently established under Dr (afterwards Sir James) Hector, but with the foundations of its investigation laid by Hochstetter. He also mentioned the field of botany, and the appearance of Hooker's Handbook, also zoology with special reference to the problem of the moa, and after considering the natural sciences as being most obviously those which would concern future investigators, he went on to deal with the physical sciences, including meteorology, terrestrial magnetism, and finally ethnology and specially the study of the Maori race.

The chief motive power behind the new Institute was provided by the three men just mentioned, Hector, Haast, and Hutton, but there were other active workers in the early years, notably Sir Walter Buller, J. Buchanan, T. F. Cheeseman, W. Colenso, R. W. Fereday, T. Kirk, T. W. Kirk, W. M. Maskell, Ed. Meyrick, T. H. Potts, W. T. L. Travers, and, later on, before the passing of the century, Charles Chilton, G. V. Hudson, T. J. Parker, D. Petrie, G. M. Thomson, all associated with natural science, and one need only

mention such additional names as those of W. Skey, A. W. Bickerton, and George Hogben to realise that the physical and chemical sciences received no unworthy attention. The importance of ethnology was fully recognised in the work of S. Percy Smith, Ed. Tregear, and A. Hamilton.

We must express at this stage our recognition of the great work done in the early days of the Dominion under trying conditions and without modern facilities, and specially so in the case of the pioneering explorations, both geographic and scientific, into an unknown land. While certain areas of the country, especially the eastern part of the South Island, were no doubt always easy of access except for rivers—and even here they took their toll, e.g., Dr Sinclair, the botanist, was drowned in the Rangitata River—nearly all the North Island and all of the West Coast of the South Island was covered with almost impenetrable bush. The means of access, if not through heavy undergrowth, lay along the shore, up rivers by wading frequently in the water, or along mountain tops above the scrub line. The journey of Sir James Hector through South Westland and Western Otago in the year 1863, when he crossed the shoulder of Aspiring, one of the mountaineering feats of the century, was a notable achievement. With this pioneering scientific expedition must be ranked the exploratory work done by Haast on the West Coast, Bidwill's trip into the centre of the North Island, Colenso's numerous expeditions into various parts of the North Island, and especially his crossing of the Ruahines, and Reischek's lonely stay in the West Coast Sounds

It must not be supposed, however, that during this period all scientific work in the country was done under the auspices of the Institute or published by the Institute. The "Geological Survey" and "Colonial Laboratory," under Sir James Hector, issued annual reports and bulletins as well as systematic monographs dealing with various groups of animals living and fossil. And there were also publications of such monumental works as Buller's "Birds of New Zealand" and Owen's descriptions of moa bones sent to him in London from time to time.

A comparison of the state of knowledge of our land in 1900 with what existed in 1867 emphasises the great progress of investigation, and the increasing volume of results. They were helped to some extent by the foundation of the New Zealand University, but this can hardly be said to have achieved substantial success in the way of scientific research by the end of the century, although there were indications of coming change. Up to this point, and for a little longer, the chief stimulus came from extra academic sources, from the devoted work of private individuals in their spare time, and of professional men in departments somewhat foreign to their usual routine. It should be noted all the same that even before the end of the century Rutherford had started on his career of scientific conquest, and the University is quite justified in taking credit for having set his feet on the path he was to follow.

During this period, the management of the business side of the Institute was in the hands of Sir James Hector, and it became the recorder of the work done by its members. It was, however, little more than a publishing institution centralised in Wellington. In the opening years of the new century, matters approached a crisis, and largely through the dominating influence of Captain Hutton, the governance of the Institute was reorganised, more representation on the governing body and more power given to the local societies, and new vigour was infused into the somewhat dry bones. Captain Hutton became the first President of the reconstituted body. For the next 30 years progress was constant, and the output of scientific work increased, and it must be admitted that its quality was also substantially improved. I am not guilty of making invidious distinctions when I say that the outstanding figure of this period is Dr L. Cockayne. I will not mention any other living member, although many have done great and meritorious service, but merely those who have passed away after bearing aloft the lamp of knowledge: Charles Chilton, G. M. Thomson, Augustus Hamilton, T. F. Cheeseman, D. Petrie, H. Hill, H Suter, A. McKay, J. A. Thomson, P. G. Morgan, and Elsdon Best. By far the majority of these men were connected with natural science, but there had been an increasing amount of investigation into the physical sciences, and this is reflected in the publications in the Transactions. While natural science has a particular appeal to the country which has furnished the material for study and only indirectly to the world as a whole, the fundamental feature of physical science is that it deals with the fabric of the globe and the universe, knows no confines, and therefore makes an appeal to the whole scientific world and even to philosophy, and its investigators seek publicity in those directions in which the world-wide audience is most easily reached. It must be admitted that the present Transactions of the New Zealand Institute are hardly the most appropriate vehicle for bringing a discovery in physical science before the world, but it is hoped that this condition may be in process of changing. One can remember that the first paper by Lord Rutherford, his first contribution to science, appeared in the Transactions. With such an excellent precedent no apology need be offered for the printing of papers in physical subjects in our Transactions, and it is to be hoped that within a measurable time they may be regarded as quite an appropriate medium for introducing new features in that sphere to the world at large.

And now, in this year 1934, we have a change of name to the Royal Society of New Zealand. The chief reason for this has been the desire to bring its nomenclature into line with that obtaining in other parts of the Empire, and at the same time to remove the ambiguity arising from the fact that there are other institutes in New Zealand with functions analogous to those of the New Zealand Institute, in other spheres with which it might be confused. His Majesty the King has graciously permitted the use of the title "Royal," so that this country will follow the precedents that have been established in so many parts of his dominions.

I must express the sincere regret of the Society that His Excellency the Governor-General is not present to deliver the inaugural address. Who is more fitted than he to preside at this ceremony and to perpetuate the custom that at critical stages in the history of our Society we have had the presence, active sympathy, support, and inspiration of His Majesty's representative in this Dominion.

This brief sketch of the history of the Institute discloses that one important purpose for which the Institute was founded has been neglected, viz., the encouragement of art and literature, and the very title of some of the branches indicates a further aim, viz., philosophy. Art has been entirely neglected except in so far as Maori art comes within the definition. Literature has received scant recognition, though there is an interesting contribution by Johannes C. Andersen on Metre, dealt with on a scientific basis. So the aims of the founders of the Society in those directions have not been realised. There are a few more papers dealing with metaphysics and philosophy, and these are almost entirely in the early years. There has been a great falling away.

The main activities have been in the direction of encouraging scientific work by providing means for publication, and this is, after all, a most important function of such a body as the Institute. The opportunity to publish the results of work is a most real form of encouragement. One of the aphorisms of Professor W. M. Davis, whose death was referred to at an earlier meeting to-day, was "Publish or perish." Davis applied the remark to individuals, for he went on to say, "If it is worth doing, it is worth printing!" If no opportunity to print is afforded, then the well of inspiration dries up. It may also be applied to societies, for this generally disconsidered function of such a society as this is really the main stimulus to a vigorous existence.

One thing, however, stands at the same since the foundation of the Institute, viz., the amount of the Government grant. It is now £500, and it was the same in 1866, notwithstanding the great increase in population and the vast increase in wealth. This lack of Governmental financial support has thrown a heavy additional burden on the constituent societies, and the result has been a serious crippling of their activities, and a decrease in the amount of money spent on their libraries. This particular financial stringency cuts at the root of all research, for without libraries or with poor libraries, original work becomes almost impossible. It is to be hoped that when the depression lifts the amount of the grant may be restored to what it was for a considerable intervening period, viz., £1500. And it could very well be increased beyond this amount.

A very serious matter related to the want of funds, and adversely affecting research throughout the country, is the delay and difficulty in publication. The Society has done its best in that direction, aided by a substantial grant from the Carnegie Trustees, and perhaps the restriction in the funds available for this purpose has resulted in the raising of the standard of accepted contributions, which is all to the good, but recently it has been found impossible to print all worthy

papers, or to print them only after considerable delay. This disability has a wider incidence, and one regrets the delay in publishing material in the case of scientific departments, which are, of course, not connected directly with the Society. There appears to be accumulations of years, and it may be a decade before they can be dealt with. In some cases the contribution will be quite out of date, or the value substantially lessened, and it may be finally advisable to decline publication. This state of affairs has a very deleterious effect on workers, especially the younger ones, who feel themselves stifled in their endeavours, and at a time when expression to them is vital; it is hoped that some means may yet be devised to aid publication.

It is an extremely wasteful method of economy to check research during depression. As far as this country is concerned, it would be an excellent investment to encourage research at such a time as the present in order that the reward may be reaped subsequently. One form of encouragement is the provision of adequate means of expression.

In this respect Australia sets us an excellent example. There appears to have been no slackening in the activities of the Commonwealth Department of Industrial and Scientific Research; the examination of all problems connected with the primary productions of the country is carried on with vigour, and the publications which the department issues at frequent intervals indicate its appreciation of the value of the regular publication of results.

While the amount of money contributed to research purposes by our own Government compares very favourably with that devoted in Australia, there is no doubt that the volume of publication in the Commonwealth far exceeds what is produced here, even if allowance is made for greater population and wealth, a more extended and diversified land, a wider range of industries, both primary and secondary, and consequently the existence of more numerous problems awaiting solution.

In countries other than our own badly affected by the depression, the amount spent on research is enormous, and shows that the authorities are fully alive to the advantages accruing therefrom. For example, during 1931 England spent £800,000 on special research departments, of which £464,000 was spent on agricultural research. Canada spent £400,000 on research laboratories, and the United States £6,000,000 on agricultural research alone. These are governmental expenditures, and leave out of consideration the vast sums spent by corporations and private individuals.

During the period from 1900 onwards, scientific investigation was materially aided by:—

(1) The increasing efficiency of University training.

(2) The reorganisation and the establishment of scientific Government departments, finally placed under the Department of Scientific and Industrial Research.

(3) The establishment of institutions like the Cawthron Institute and the development of museums.

The effect of the first has been very pronounced since better facilities such as laboratories and libraries have been provided, an increasing number of scholarships have been established which have enabled promising students to continue their work in Europe and America. In fact, nearly all students who would be likely to benefit materially by such experience are able now in some way to reach the schools of the Old World. The effect of this on the Institute has been direct, but the Institute has reacted on the University as well, since it has enabled students to publish results in many cases, and provided a contact with extra-academic influences; in fact, some men external to the University, such as Dr Cockayne, have exercised an influence comparable with or even exceeding that of the staffs of the University itself.

The chief difficulty is the paucity of the staffs of the university colleges, the necessity of their devoting so much of their time to actual teaching of students in lower grades, and the lack of a central university where research into special New Zealand problems and, of course, others can be prosecuted. Perhaps at the present time it is more economical to send promising students to lands where research laboratories now exist, but the time will come when such a central institution must be established. The University suffers from the absence of a central home and source of inspiration

The scientific departments of the Government, established on modern lines since the beginning of the century, have stimulated research to a marked degree, and specially so since their grouping under the Department of Scientific and Industrial Research. Behind all these there is some direct utilitarian purpose, notably the development of the country's resources—agricultural, mineral, forest, etc.—whereas the main influence of the Royal Society is directed towards pure science, though not exclusively so There is no real difference between the two branches of pure and applied except that the former is devoted to the welfare of the world as a whole without regard to persons, and the latter is directed to the advancement of the interests of some particular country, or individual or group of individuals. For this reason applied science requires a high standard of accuracy in its application. When the proper expenditure of a large sum of money is dependent on the correct solution of a problem in all its phases, a public or private corporation demands more careful examination of all the surrounding circumstances and related factors. In pure science the mere reputation of a scientist is at stake, and as long as his own conscience is satisfied, he feels no further responsibility, and though he may care a great deal, the world as a whole certainly does not. All the same, the method of approach to the problems concerned is the same in both cases, and must be in both subject to the same rigorous controls.

The scientific method of approach to problems in applied science has a much wider incidence than some people think. It is usually believed that inventions are the result of some sudden inspiration, but I have been told by a well-known Australian—I should, perhaps, say New Zealander—that this is not the case. In his experience,

inventions are due to the arriving at a correct solution of a definite mechanical problem, and the reputation of an inventor depends on the skill shown in solving such a problem.

I need not make mention to such an audience as this of the cases where men working in the laboratory on a purely scientific problem, and with no thought of future gain, but only the advancement of the cause of truth, have demonstrated principles which have led not only to scientific fame, but to commercial results of world-wide incidence, the happiness of millions, or their misery, and the fortunes of hundreds of individuals.

Then, too, the establishments like the Cawthron Institute, the Portobello Fish Hatchery, and the museums of the country afford facilities for scientific investigation. It may be a momentary phase at the present time to decry museums as storehouses of collections of plants and animals, of ethnological and historical material, but such material has to be preserved as a record, and for the information of future workers, and where else can such be housed? Unless, indeed, the modern development will be in the direction of divorcing this aspect of museum work from the educational and providing entirely distinct establishments with different utilities and aims. I believe that I am correct in saying that, considering their resources and opportunities, the value of the scientific work contributed by museums in this country is not excelled by that of any other institutions. There have been, in addition to the regular plans of investigation carried out in our departments, notable contributions by men of standing acting under instructions from such departments, but really outside them, and also those made by persons belonging to public institutions in directions where their strict duty hardly lies. I refer to such works as Hamilton's "Maori Art," "Cheeseman's "Manual of New Zealand Flora," Suter's "Manual of Mollusca."

There is, lastly, that group of so-called unemployed or leisured class who in Great Britain have been the glory of its science—men of independent and untramelled thought, who have worked for the mere love of truth, have acquired fame, and furnished epoch-making contributions to the cause of science—men like Charles Lyell and Charles Darwin. This race is fortunately not extinct here. Its individuals are usually connected with natural history, perhaps because physical science and chemistry require laboratories and equipment beyond the resources of private persons, however wealthy, but one knows that the spirit is alive if the opportunity does not present itself.

The most striking features of the scientific development of the past 30 years has been (1) the astounding advance in the fundamental sciences of physics and chemistry, and (2) the success of the application of the methods of these sciences to the so-called natural sciences. This tends to a much more rigorous investigation of problems and the elimination to an increasing extent of the personal equation. When an investigator has to rely very largely on his own intuition, the results vary very greatly with the capacity of the investigator. If

he is a genius, then his results may have far-reaching effects, but in the hands of a moderate observer they become useless or even dangerous.

Geology has been held to be a very inexact science, seeing that in geological accounts there is the too-frequent use of the words, *probably, perhaps*, or *it may be so.* I well remember Dr T. A. Jaggar, Director of the Volcano Observatory at Kilauea, saying that he hoped that no geologist would succeed him for this reason. He was, after all, a geologist himself, but he wanted a man trained in physical methods of exactness, and his suggestion was that geology would benefit very greatly if it adopted these methods. The days are gone, or are fast going, when a single geologist will be fully equipped for field work with a hammer and a compass, and before long no party of the geological survey will be sent out without a geophysical equipment as well. Geology has practically shed crystallography and seismology, and it may shed other branches when the true physical methods invade its debatable zones. Palaeontology in some respects as a geological instrument has become almost exact, though as a biological study it can hardly make that claim. This application of physics and chemistry to botanical and zoological problems is becoming more and more effective, and there are indications that the day of the pure systematist is done. I am not decrying his work—organisms must be classified, described, and arranged, but this is no longer the most important phase of biological study. The increasing application of physical methods to such problems appears to me to be the most striking phase of the last third of a century of the Institute's history.

One disappointing feature of the study of natural history in this country is the general failure of both old and young to show an intelligent interest in the plants and animals of the land where they live. In England, in nearly every small town there is some person who takes a lively interest in the natural history of his neighbourhood and has made some typical collection of it, whether of insects, or plants, or birds, or fossils. One hardly ever sees this feature displayed here. There is no general love or interest in nature, and the reason for its absence is not obvious. It does not appear to be due to lack of school training, for these naturalists of Great Britain appear to have the quality born in them. I do not think it has anything to do with the training, for the few people of this type that I have come across in New Zealand owed little or nothing to help at school. The race is still the same, and it should possess the same instincts. One great work of a society such as this might be to revive this sleeping instinct, for when developed again, its help to science will be manifest. The notable experiment of the Auckland Museum in the direct encouragement of the study of natural history will be watched with interest, and with hope that it may serve to remedy to some extent this defect in the scientific outlook in the younger members of the community.

This introduces the reference to one of the most important interests of the Society, viz., the supervision of certain of the national parks and sanctuaries of the Dominion, such as the Tongariro National

Park, the Arthur Pass National Park. On the Boards of Control of some the Society is not directly represented; still, it is vitally interested in their management. Recently it has interested itself in having the Auckland Islands as a whole and the Kermadec Islands declared sanctuaries, and it views with cordial approval the removal of the country at the head of Lake Roto-iti, in the Nelson province, from land selection.

These national parks are intended to afford to our unique flora and fauna the protection necessary for their continued existence under natural conditions, and were it not for introduced pests they would thoroughly effect their purpose. But stoats, little owls, deer, and chamois are taking their toll of bird and plant life, and certain alpine plants are threatened with extinction by the latter, or at any rate a material reduction in numbers in the areas which are their particular habitat. This makes it necessary that the introduced pests should be controlled, if not actually exterminated. The Government should set its face resolutely against the importation of all such animals, whether in the name of sport or otherwise. One cannot tell what may eventuate at times in the case of an animal relatively harmless in its own home, where it has developed pari passu with biological controls, when it is removed to another land where such controls do not exist.

The Society should also emphasise the necessity of having thoroughly representative collections of living plants established under suitable conditions. There is the Otari Open Air Museum at present in existence, and the Arthur's Pass Board has recently considered a scheme for the formation of an Alpine Garden at Arthur's Pass.

These national parks and sanctuaries will ultimately be found of inestimable value when the public of the Dominion and, above all, its younger members, learn to appreciate to the full the natural beauties and treasures of our land, and to realise that it is truly a "precious stone set in the silver sea." Their attraction for overseas visitors and scientific men will be perpetual.

One mentions here the question of national parks and sanctuaries, since the reputation of the Society as a scientific body has been chiefly established by the study of the fauna and flora of the country, and it would be an ill service to posterity if we did not hand on, in as perfect a form as possible, those materials for study which were once available. Not only will the work of pioneers be better appreciated, but it will afford opportunities for investigation which we are confident will be continued in the future. During the progress of settlement, wasteful and almost criminal methods have reduced our heritage, have actually destroyed portions of it, have exterminated many unique plants and animals; but the present public conscience will not allow it to be frittered away, and we must always be grateful for that vigilance shown by such organisations as the Bird Protection Society, which, without being actually scientific bodies, are aiding materially in scientific research.

A disability of a Royal Society in this country, and one calculated to lessen its effectiveness very seriously, is that it has no central home. When matters affecting scientific politics must be

considered and the full weight of the society exerted to secure a certain end, Sydney can speak authoritatively for the whole of New South Wales, Melbourne for Victoria, and Adelaide for South Australia, but there is a difficulty as far as New Zealand is concerned. While in one way it is an advantage to have a diffusion of interest and some amount of decentralisation, the increased effect of a superior central body is manifest when the combined influence of the Society has to be employed So, for the same reason, New Zealand has no true university; both society and university are weakened by the geographical lay out of the land. It seems difficult to meet this objection in a satisfactory manner as far as the Society is concerned, but with regard to the university it can be met by establishing a central research institution to which present colleges will be subordinate as indicated previously, or to raise the latter to the dignity of separate universities. It seems a long shot to suggest that ultimately we may have a Royal Society's House in New Zealand where its meetings will be held, its library housed, where portraits of its distinguished members may be displayed for all time; but the Society will not have a full measure of prestige till some such home is provided and maintained in adequate state.

There has been a considerable amount of criticism recently both anonymously in the public press and in meetings of at least one of the local branches in that the Society is not fulfilling its functions adequately and not acting as the leader in scientific matters that its history and prestige demand. In my opinion, the activity of the Society and the interest it has shown in scientific matters has never been greater, only other departments have arisen which have taken on some of the functions once belonging to the Society. At one time the Institute directly through its head was the adviser to the Government on almost all matters relating to science; now there is an influential and well-staffed Government department directly under a Minister, and the proper source of advice is the body of expert opinion of that department. There is little or no need to consult such a body as the Institute or the Society into which it has developed. There are other departments of the Government as well which have a scientific staff. All the same, the Society exercises, and will continue to exercise, both through its individuals and as a corporate body, a watchful yet sympathetic eye on scientific matters and the governmental relation to them, and were the necessity to arise, it would not hesitate to place its views before the powers controlling the country.

A suggestion has been made that the Society's annual gathering should be something more than a mere business meeting, that pronouncements should be made by the presidents and others on important matters in the scientific world, and that the feature of such a meeting should be the Presidential Address, following on the custom of similar societies in Australia and elsewhere. A difficulty arises in this connection from the geographical condition of this country. Instead of having a central capital dominating other centres of population in which are located a large proportion of the scientific

workers as residents, we have in New Zealand four centres of subequal size, with a relatively equal population directly interested in scientific matters, and other centres still more scattered. Wellington has certainly some advantage in that it is the seat of government, but the advantage due to this is not overwhelming, and it should not give to the capital the exclusive right to the place of the delivery of the Presidential Address—an arrangement should be made for a regular change of venue. There has been precedent for this, in that on occasion the annual meeting of the Institute has been held in Auckland, in Christchurch, and in Dunedin, and it is also specially mentioned in the Act. Although it is slightly more costly to make a change from Wellington, yet in normal times this extra cost should be met in the interests of the vitality of the Society. The delivery of a true Presidential Address, and not a mere summary of business, would be a manifest advantage, and help and encourage appreciation of the Society's work and functions throughout New Zealand. It would remove very largely the conception of the Society as being merely an association of scientific men and other representative men meeting once a year in Wellington to transact pure business, appoint committees, and hear their reports, and from time to time to make awards of medals, awards which are at times strongly criticised. As long as the criticism is not factious and for the purpose of creating trouble, it should be welcomed as indicating an active interest of the individual members in the Society's affairs.

What, then, are the ultimate objects of this Society? I cannot do better than quote from Bacon's "New Atlantis" where he describes the establishment known as the House of Salomon. He says: "The end of our foundation is the knowledge of causes, and secret motions of things, and the enlarging the bounds of human empire to the affecting of all things possible."

A statement from the man who foreshadowed the foundation of the Royal Society forty years before it was actually founded, who placed the principles of scientific reasoning on a sure basis, cannot help but be of value although science was in its infancy when he wrote the words. He stressed the necessity for observation especially in matters pertaining to natural history, but did not neglect what is now called physical science based strictly on observation, for in the close of his description of his Royal Society he says: "Lastly, we have circuits of divers principal cities of the kingdom; where as it cometh to pass we do publish such new profitable inventions as we think good. And we do also declare natural divination of diseases, plagues, swarms of harmful creatures, scarcity, tempests, earthquakes, great inundations, comets, temperature of the year, and divers other things; and we do give counsel thereupon, what the people shall do for the prevention and remedy of them."

This was written 300 years ago (1626), but it has a modern outlook, although the conjunction of the various phenomena is hardly modern. We have a forecast of our Health Department, the investigation of insect pests, regular meteorological and astronomical observations, and the suggestion that such institutions must give

advice concerning them to the general public. There is also provision for the holding of meetings in various parts of the kingdom. Allowing for an archaic diction, it is just such a programme as might be adopted by our Department of Scientific and Industrial Research, but visualised by Bacon as a programme for a Royal Society, in the way of using scientific investigation for the benefit of mankind.

But can we make any prediction as to how a present-day Royal Society will develop? If we consider the position of scientific research in 1866 as compared with its position in 1903, and again the position in 1903 with that in 1934, we cannot fail to be struck with the fact that not only has there been a marked acceleration in the latter period in the rate of progress, but also has there been sudden and striking advances—the mutations of biological evolution. Since 1903 the advance has been bewildering, and it is true of every department, but specially of the fundamental sciences, physics and chemistry. Investigations are reaching out further and further, in one direction almost to the infinity of space—if, indeed, this exists—and in the other to the infinity of minuteness. There is also an approach of science to philosophy, and ultimately the aims of the founders of the Society may be realised in that direction, for philosophy may become merely a branch of science or science of philosophy.

If one may hazard a prediction, the main advance will probably be first of all in the increased application of the methods and theories of physics and chemistry to the mechanics and perhaps the actual origin of life itself. This does not seem too much to hope if a commensurate progress is to be maintained as compared with that of the early parts of this century. Whither this may lead it is impossible to say, unless it is to result in the truer appreciation of an all-powerful and beneficent Creator. The impossibility of prediction is emphasised by Eddington in the conclusion of his book on the "Nature of the Physical World," where he says:—

"If the scheme of philosophy which we now rear on the scientific advances of Einstein, Bohr, Rutherford, and others is doomed to fall in the next thirty years, it cannot be laid to our charge that we have gone astray. Like the systems of Euclid, of Ptolemy, of Newton, which have served their turn, so the systems of Einstein and Heisenberg may give way to some fuller realisation of the world. But in each revolution of scientific thought new words are set to old music, and that which has gone before is not destroyed but refocussed. Amid all our faulty attempts at expression, the kernel of scientific truth steadily grows."

In the pursuit of this varying and elusive truth, we feel confident that this Society, in conjunction with others, will play its part, and that in their triumphs as well as in their failures it will be associated. It has our hopes for a continued and increasing success, and, personally, I conclude with the simple additional wish, *Esto perpetua.*

OBITUARIES.

Henry Hill

Mr Henry Hill, of Napier, was one of the oldest members of the New Zealand Institute. He was elected a member of the Hawke's Bay Philosophical Society in 1883, and on the reorganisation of the New Zealand Institute in 1903 he was appointed the representative of that Society on the Board of Governors. This position he continued to hold until his resignation in 1931.

The energy and enthusiasm of Mr Henry Hill were widely recognised. Though he was engaged for many years in arduous educational work he constantly devoted his spare time to scientific research. Vulcanology particularly interested him, and he became an early and eager student of the Taupo volcanic region and made frequent ascents of the lofty summits of the cones of the Ruapehu group. The river systems past and present of the Hawke's Bay-Wairarapa area was another favourite subject of his study. He has also made important observations on water supply and on oil-bearing structures.

Mr Hill had a most stimulating influence, and did much to arouse and maintain interest in the study of natural science. After retiring from educational work he displayed much energy in civic and political matters. He was Mayor of Napier from 1917 to 1919, and was an aspirant for political honours. Of late years he lived much on his property at Lake Taupo, in the midst of the volcanic surroundings which had such a great fascination for him.

Energetic to the last, he over-exerted himself at the age of 83, and this was the cause of his death. Locally he was often regarded as the scientific authority of Hawke's Bay, and his death seemed a personal bereavement to many who had actually known him little but by name.

Professor D. M. Y. Sommerville

Duncan McLaren Young Sommerville, a son of the Rev. James Sommerville, was born at Bewar, Rajputana, India, in 1879. He was educated in Scotland first at Perth Academy and then at St. Andrew's University. His wide interests both literary and scientific showed themselves early. After a most brilliant academic career he was appointed lecturer in the Mathematics Department at St. Andrew's, and held that position till his appointment in 1915 as professor of pure and applied mathematics at Victoria University College, Wellington, New Zealand. In 1905 he was awarded the degree of D.Sc. for a thesis on Topology in Non-Euclidean Space He was later elected Fellow of the Royal Society of Edinburgh, Fellow of the Royal Astronomical Society, Fellow of the New Zealand Institute, and in 1928 was awarded the Hector medal for his researches in non-Euclidean geometry. While interested in all branches of mathematics and astronomy, he had altogether unusual ability in geometry. In a sympathetic notice in "Nature," Professor H. W. Turnbull concludes: "There has passed from Scotland one who had already become her leading geometer of the present century."

Professor Sommerville was the kindliest and most unassuming of men. As a teacher and lecturer he was extremely lucid, and sympathised with the difficulties of the ordinary students. His lectures and text books are models of exposition. It was amazing the amount of extra work he was able to achieve both in elegant summaries of existing knowledge and in original work. His "Elements of Non-Euclidean Geometry" (1914) and "Analytical Conics" (1928) are both on the select list of the "Mathematical Association." His "Introduction to the Geometry of n Dimensions" (1929) and "Analytical Geometry of Three Dimensions" (1934), of both of which works I had the pleasure of reading the proofs, are remarkable expositions of difficult subjects. He had the pleasure of seeing the last book in the press before he died. Of this last book an able review in the Nottingham Guardian says: "Students will find it absorbingly interesting and exhaustive." In the Cambridge Review Professor H. F. Baker, probably the greatest living geometer in England, says: "The volume under review is one which must

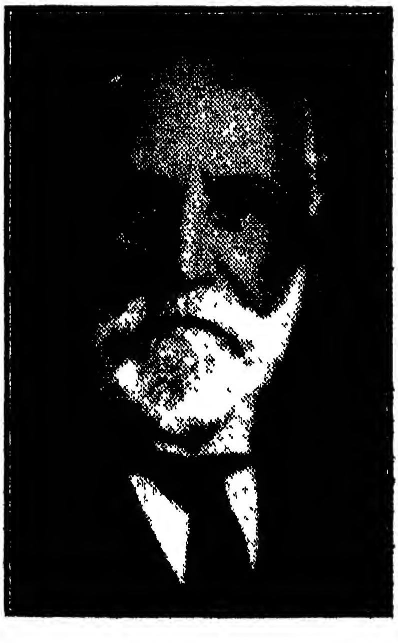
gladden the heart of anyone who is anxious for the spread of a wider knowledge of solid geometry among English-speaking people."

Professor Sommerville did not by any means confine himself to mathematics He was one of the founders of the New Zealand Astronomical Society and its first Secretary. He was Chairman of the Library Committee of Victoria College, and took a deep interest in library affairs. As was natural for a great geometer, he was very skilful with his hands, binding books, constructing geometrical models, and painting very pleasing landscapes. His very fine collection of models has been generously donated to the College by Mrs Sommerville. In honour of his great work for the College, a number of his friends have purchased an important section of his library for the College.

His death at the early age of 54 is an irreparable loss to his many friends, to Victoria College, and to the world of science. To Mrs Sommerville, who had many interests in art and literature in common with him, would we extend our deepest sympathy.

F. F. MILES.

George Malcolm Thomson (1848-1933).



BY the death of the Hon. G. M Thomson, M.L.C., F.L.S., the New Zealand Institute loses one of its oldest members, one who was held in high esteem not only for his genial personality, but also for his keen and active interest in science, especially Natural History.

Born at Calcutta in 1848, he came to New Zealand when he was twenty years of age, and, except for three years, spent the rest of his life in Dunedin. He joined the teaching staff of the Otago High Schools in 1871, and a few years later became the Science Master, teaching both Botany and Chemistry, a position which he occupied from 1877 till 1903. He cared nothing for syllabus or for examinations; his method was such as to excite the real interest in his subject; his aim was to awaken in his pupils a love for Nature, and this he succeeded in doing, both by his work in the classroom and in his walks round the Town Belt. But he had many other interests: he was at a younger age an active football player; and he became a

member also of the B Battery, in which he was a captain. It was during his time at the High School and while he was supervising the target shooting by the cadets that he received a shot in his foot, which had to be amputated. Nevertheless, though sadly hampered for the remainder of his life, this did not seriously interfere with his taking part in botanical excursions.

Another and a more lasting hobby was music, and for several years he was an active member of the Dunedin Orchestral Society.

But these interests did not satisfy G.M.T.; he took a very keen and very active share in a variety of social work, for the betterment and education of the young people, and for the provision of evening classes for those who had not had the opportunity of attending the High School; for this was long before the system of Free Places. He was the founder in 1889 of the Technical School in Dunedin, where night classes were provided; and was its superintendent and chairman for some ten years, and even after that remained on the committee. He was one of the chief founders of the City Mission, of which he was likewise president; and for twenty years was president of the Y.M.C.A.

There are few men who spent themselves so ungrudgingly, and without fee or reward, for the public weal.

After resigning from the High School, he carried on the business of analyst for some years, but relinquished it on being elected to the House of Representatives for North Dunedin, in 1908; and he remained a member of the House till 1914 Four years later he was appointed a member of the Legislative Council, in which he sat till his term expired in 1932. During his parliamentary career and as a Governor of the New Zealand Institute he was constantly advocating the introduction of Natural History into the school curriculum, but this was one of the few things that he had at heart which he did not see fulfilled.

But he will be known best and for the longest time for his work in science. Mr Thomson was the last of the old-fashioned naturalists, in the widest sense. He was, too, an amateur naturalist, and I do not use this term in any derogatory way, for in the past much of our knowledge of zoology and botany was built up by men who took up the study of plants and animals out of pure love of the subject, and as a hobby, apart from their daily work, and unconnected with any university appointment; men who have received no training such as is provided now in universities and colleges. To-day everything is organised, and amateurs are fewer and fewer as the sciences become more and more specialised; all is worked according to some syllabus. Thomson was not shackled by such chains; he worked along his own lines.

Mr Thomson was elected in 1872 a member of the Otago Institute, which had only been founded in 1869, so that he was practically co-temporary with it. He was elected to the Council of the Institute in 1875, and remained a member of it till the last. He acted as secretary on three occasions: in 1878-80, in 1887, and again in 1902.

He was president three times: in 1881, 1901, and lastly in 1919. He was one of our representatives or Governors of the New Zealand Institute from 1905 to the last: he was president of that body in 1907-8. When the Fellowship was established in 1919, he was naturally one of the Original Fellows of the New Zealand Institute. He was editor of the Transactions in more than one year. Indeed, last year he saw the work through the press. He was awarded the Hector medal in 1930 for his botanical work.

In 1884 he was elected a Fellow of the Linnean Society of London, and was a member of other scientific societies.

In addition to a number of zoological articles contributed by him to the "Annals and Magazine of Natural History," Mr Thomson published some thirty-three papers in the Transactions, the first in 1874, the last in 1927. Of these fourteen related to the crustacea But his interests were almost equally divided between animals and plants; and we might divide these papers into three periods. The earliest dealt with plants, then come the crustacea, and his later ones with fishes and fisheries, but each period overlaps the other.

His first paper in 1874 dealt with introduced plants in the neighbourhood of Dunedin He emphasised the importance of cataloguing these naturalised foreigners He returned again and again to this subject, in 1900, and in his large work on the "Naturalisation of Plants and Animals in New Zealand" He was interested in the gradual change in the vegetation of New Zealand, the gradual disappearance of the native plants and the invasion of the introduced ones. Another problem that he tackled was the origin of our flora, a subject which he took as his presidential address in 1881 He explained the similarity of our flora with that of South America and Tasmania by an appeal to the former existence of an extensive Antarctic Continent "which had in all likelihood alternations of climate . . . and during some of its warmer epochs it would be invaded by plants from South America. These would become spread round the south pole, from thence to be distributed radially to the countries lying north, as the climate again altered." And some of these would have reached New Zealand. The suggestion is in accord with that held by zoologists to account for the occurrence here and in South America of similar animals

A third subject which attracted Thomson was the fertilisation of flowers. In 1878 appeared his paper on "The Fertilisation of Our Orchids," flowers in which the apparatus for pollination has undergone extraordinary modifications. He describes the arrangements in ten species.

In the same year he studied the Violas. It has long been known that in the violet there are, in addition to the bright and fragrant flowers to which insects are attracted, and so cross-pollinate the flowers, several small, colourless flowers closed so that self fertilisation alone is possible. Thomson examined two species of native Viola as well as the "cleistogamic" flowers of some other genera, such as *Melicope simplex.* In 1880 he published a paper of forty-seven pages

in which he enumerates the species actually examined by him in the attempt to ascertain by what agencies the transference of pollen was effected. Of the 433 species he studied, he found that 30 per cent. had conspicuous flowers; 21 per cent. of the flowers were conspicuous "by association" such as the *Compositae;* and 49 per cent. were inconspicuous, including the grasses. He then tabulated the flowers according to colour, to fragrance, and to honey secretion, and so on. He proceeded to examine one by one the representatives of the natural Orders, describing the structure of the flower and noting any arrangement of the stamens, etc., that are pertinent to the matter in hand. The paper illustrates his methodical and careful work. In 1927 he returned to the subject, and in a much more extensive paper gives a summary of all that was known or has been recorded as to the fertilisation of our native flowers by birds and insects. The accumulation of the facts must have involved a great amount of reading of papers relating to the plants, and others relating to insects. He remarks: "Botanists do not trouble themselves with the insects that visit flowers which they are collecting; and entomologists are seeking the insects themselves and seldom note the plants they are found upon." Yet Thomson was able to dig out of the scattered literature and to tabulate some 60 species of insects of different groups —Diptera, Coleoptera, Lepidoptera, Hymenoptera—as visitors of flowers. He enumerates the flowers so visited, or which are constructed in such a way as to attract insects, and quotes always the observations of others; it is a very valuable paper, and indicates the industrious and painstaking method he followed.

This sort of Botany is now out of favour and, indeed, unnecessary, but we must remember the date at which Thomson was making these investigations. The "Origin of Species" had been published late in 1859 and had shed a new light on the study of natural history; Darwin had raised it from an arid collection of unrelated facts to a real science of living things in which each one is adapted in some way to meet the effects of the environment. Both zoologists and botanists were, during the 'sixties and 'seventies, stimulated to look at nature from a new aspect. Darwin had published in 1862 his book on "The Fertilisation of Flowers," and showed the variety of modifications presented by them to effect cross pollination; and in 1876 there appeared his work on the "Fertilisation of Orchids." So Thomson, being a staunch follower of Darwin, was applying to the New Zealand flora what Darwin had done for the European, and he found that the generalisations then made held for our flowers. To-day, botanists having assimilated these generalisations, apply themselves to more complicated relations of plants to their surroundings—they study Ecology.

In 1898 Thomson wrote a paper on the Study of Natural History in which he referred to the lack of powers of observation of natural phenomena in most people, and in order to stimulate this and an interest in his favourite subject, the Otago Institute, on his suggestion, offered prizes to pupils of the primary schools for the best diary

or other record made throughout a year of such observations by the pupils themselves.

In 1909 Thomson published a little book, "A New Zealand Naturalist's Calendar," which was a reprint of a series of articles which he wrote for the Otago Daily Times. In the introduction he wrote: "I have tried to keep my eyes open to the beauties of nature. I have recorded facts and incidents which interested me; . . . they do not profess to teach anything new." A charming little work it is; he tells in his excellent English of his walks about Dunedin, the Town Belt, and even further afield at Moeraki . . . and tells of the plants and insects and birds that he sees. The diary is divided into months so that one may find what plants are in flower at any time of the year.

But Thomson had not confined himself to botanical problems, for already in 1878 he commenced that series of papers on Crustacea which was to prove his real life work, by which his name will be remembered by zoologists. In 1878 he had four papers on the group in the Transactions for the year

He first tackled the lower forms, minute fresh-water crustacea —the Daphnids, Cyclopids, Cyprids. It was a new ground; no one had done anything for New Zealand Entomostraca till he studied them and introduced to naturalists here a new realm of beautiful and active little animals. Unfortunately, the editor of that time ruthlessly reduced Thomson's excellent drawings to so small a size in these early papers as to lose much of their value. In later papers the figures were reproduced on a satisfactory scale.

In 1882 there appears his memoir on Parasitic Copepods, in which the females are so changed in form as to lose all resemblance to their class.

And so he went on, dealing successively with each of the larger groups included in the Crustacea. They are remarkable for the lucid description of external form, and the excellence of the illustrative drawings. It is impossible to do justice to this work. It is purely systematic descriptions of new genera and species, valuable to zoologists, but containing nothing profoundly new. Many of these crustacea he obtained by tow netting in the waters of the harbour and by dredging. Not only did he describe a number of these lower crustacea, but he sent home to the distinguished zoologist Sars, of Norway, dried mud from the ponds. This contained the eggs, and from this mud Sars reared a number of forms in addition to those Thomson had described. Throughout his crustacean work, he was in communication with specialists in Europe and America, thus keeping in touch with what was being done outside New Zealand.

Early in his life he had influenced the late Dr Charles Chilton to take an interest in this same group, and they collaborated in certain papers. Thomson also published in the Transactions of the Linnean Society an account of our crabs.

In 1892 Thomson discovered in the waters on Mount Wellington, near Hobart, a small shrimp-like animal which he noted was different from any crustacean hitherto known. He called it *Anaspides,* as it lacks the shield or carapace of the related forms. When his paper appeared in the Transactions of the Linnean Society, zoologists recognised that it was not only a very primitive type, but that it stood alone, and a special Order was made for it. It was an astounding and outstanding discovery to have made. It is now recognised that it has most intimate relations with a small group of Palaeozoic crustacea: and like the tuatara is a "living fossil."

We pass now to the third period, or rather line of work, for each of these varied subjects overlap in time. He turned his attention to fishes and fisheries in 1891, and though he published only four papers, they contain very valuable contributions.

The first one consists of notes compiled from records kept by light-keepers round the coast, for which the Minister for Marine supplied the men with printed forms; this paper is merely a list of those fishes and the dates and localities at which each was observed It does not add much to our knowledge, but is an example of the kind of methodical work Thomson carried out In 1897 his second paper refers to the proposed establishment of a fish hatchery, which at that time was to be situated at Purakanui. He indicated the great value such a station would be, especially in connection with the fishery industry, and with necessary legislation. He wrote: "Fishery legislation, to be of use, must be based on knowledge, i.e., observation and experiment; we are ignorant of such fundamental matters as the time of spawning, the localities in which spawning takes place, the changes undergone during the life history, the migration of fishes, the character of the food, etc." He makes some severe comments on the absurdities of many of the regulations drawn up in ignorance of these facts In 1905 he gives the complete history of his attempts to get the Marine Fisheries Investigation Station established. It was to Thomson that the present station at Portobello owes its existence. He approached the Ministers to get grants, as well as the Acclimatisation Society and the Institute. At last he got the approval of the Minister and the promise from the societies, and the station was opened in 1904. The first meeting of the Board, which was appointed by the Minister, was in 1902. George M. Thomson was elected chairman, and occupied that position up to the time of his death.

In this paper details are given of the investigations already carried out and of those commenced; the history of the trial shipment of lobsters, which was unsuccessful till later in 1912. In Vol. 45 he published the first part of what was intended to be "The Natural History of Otago Harbour." In it he gives a list of all the fishes recorded from the harbour and its immediate vicinity, and all the crustacea. He hoped for the collaboration of other specialists so as to make a complete biological survey of the harbour; but lack of enthusiasm, lack of men to carry out the work, has left the survey for future naturalists to carry out.

In his capacity of chairman of the Portobello Station, Thomson has sent in an annual report to the Minister of what has been done. And throughout the years during which the station was being hatched, and during most of the time since, Thomson bore the expense of postage, stationery, and other expenses. No one could be more generous of his time, labour, and money in any effort to bring to fruition his attempts for the benefit of others. In the case of the station, he always had in mind the help it would give to fishermen. In these later years it has been his greatest pleasure to spend time at the Hatchery working in the laboratory, and the decision of the Government to reduce the annual grant and thus to deplete the staff was a genuine grief to him He was up to the last trying to persuade the Minister to increase it even by a small amount so that the work of the station should be continued.

In 1900 he accompanied the Inspector of Fisheries on a voyage on s.s. "Doto" to investigate suitable trawling grounds, to find out where marketable fishes were most numerous, and so on. Mr Thomson made extensive collections of marine animals, which were later described by various zoologists in New Zealand. As the "Doto" travelled up the east coast of this island and entered Cloudy Bay and Golden Bay by Nelson, and as dredgings were made all the way, quite a good assortment of rare forms were, through his agency, brought back.

I must refer to Thomson's *magnum opus*, "The Naturalisation of Plants and Animals in New Zealand," which was published by the Cambridge University Press in 1922. Such a work has never been attempted for any country, and, indeed, New Zealand seems to be the only country in which it could be attempted with anything approaching success.

The history of European invasion of plants and animals dates back no further than to Cook's time, when in his second voyage he landed at Dusky Sound and later at Queen Charlotte Sound. At each place he seems to have left some few animals and seeds or plants. The compilation of such a work involved an immense amount of labour, so vast that any other man but G. M. Thomson would have been appalled, as indeed he was, and they would have given up the work. But Thomson, with that persistence so characteristic of him when once he had undertaken a thing, went through with it. He studied the records of all the Acclimatisation Societies, going as far back as possible; he got into communication with many individuals who might have knowledge of the facts or who could help him to get the facts.

The record consists of a complete list of all the mammals, birds, fishes, and invertebrate animals that have been intentionally or accidentally introduced—more than 600 species of animals from the "Red Deer to the oyster," and as many plants, if not more. It is not merely a dry catalogue, but for each animal and plant he notes the date of introduction, the place, and the person or society

responsible, and details as to whether it succeeded or died out. He quotes from people who knew the facts. For instance, he gives seven pages to the Red Deer, and nine pages to the Brown Trout.

He took the greatest pains to get the nomenclature correct and the classification, adopting the most authoritative views on such matters. He spent hours in the Museum library consulting books in order to be as correct as possible, so that the book could be used by zoologists anywhere. The work is a monument to Thomson's patience and thoroughness.

During the last few years he had been at work on a complete "List of the Crustacea of New Zealand," with outline drawings of all the species recorded in any publication in any part of the world. Had he been able to complete it, such a work would have been invaluable to naturalists the world over. He was in correspondence with crustaceologists in Europe and America, seeking their aid in tracing down to their source the description of such forms as had been described by zoologists outside New Zealand in journals which we do not see. He spared no pains to get this list complete and accurate. Even the week before his death I spent an evening with him in consultation over the work, much of it nearly ready for printing.

In addition to all this original investigation, Thomson published, in 1891, an "Introductory Class Book of Botany for Use in High Schools." It followed on the lines of what at that date was the well-known method of studying plants, but has long been discontinued. Also he wrote a handbook of the Ferns of New Zealand, founded on the specimens he had gathered.

In 1882 he founded and edited the New Zealand Journal of Science, and although his name does not appear on the title-page or elsewhere, it was known that he bore the cost of any deficit due to lack of subscribers. Its intention was to provide more frequent means of publishing original papers than the annual volume of the Transactions, and to form a means of communication amongst the scientific workers in the Dominion. It contained original articles, abstracts from scientific papers from outside the Dominion, and so on. After running for four years, 1882-85, it ceased, owing to the failure of 60 per cent. of the subscribers to pay up. But Thomson with his enthusiasm not a bit dulled, resumed the publication in 1891, when six parts were issued. But it had to die. In the first period G. M. Thomson bore the whole brunt of the cost and editorship, but in the second appearance he was aided by some six or seven others.

When the A.A.A.S. met at Dunedin in 1904, G. M. Thomson was the local secretary, and the success of the meeting was due to his energy and geniality and his organising ability.

The Dunedin Field Naturalists' Club owes its inception to the same gentleman, who in the early days accompanied members on their excursions, which were rendered fruitful and interesting by

his knowledge, always freely given. Though the original club died, yet it was revived more than once, and quite recently Mr Thomson gave an address at an indoor meeting of the members.

It was he who was instrumental in cataloguing the native plants, and having published a list of all those to be found in and around Dunedin: a comparison of later lists with the first list will indicate what changes in the flora have taken place.

Such is the record of work during nearly sixty years carried out by a conscientious and enthusiastic naturalist, equally interested in problems of botany, in systematic zoology, and in economic zoology, and in the facts of acclimatisation And though he made no definite contribution to Evolution, he was a firm believer in that philosophical aspect of biology. His life was a full one, and in spite of domestic losses he never faltered in his ideal of public service. His high courage never failed, his faith never wavered. G.M.T. gained the affection of all who knew him, and the esteem of everyone with whom he came in contact, whether in business, in his scientific, his social, or political activities.

WM. B B.

Appendix A.

THE NEW ZEALAND INSTITUTE ACT, 1867

NEW ZEALAND.

ANNO TRICESIMO PRIMO
VICTORIÆ REGINÆ.
No. 36.

An Act to establish an Institute for the advancement of Science and Art in New Zealand. [10th October, 1867.

Whereas it is expedient to make provision for carrying out the geological survey of the Colony and to establish and incorporate a public institution in the City of Wellington to be called "The New Zealand Institute" which institute shall comprise a public museum and laboratory and a public library. And whereas it is also expedient by means of lectures classes and otherwise to promote the general study and cultivation of the various branches and departments of art science literature and philosophy,

Be it therefore enacted by the General Assembly of New Zealand in Parliament assembled and by the authority of the same as follows:—

1. The Short Title of this Act shall be "The New Zealand Institute Act 1867."

2. It shall be lawful for the Governor in Council from time to time to appoint a fit and proper person to superintend and carry out the geological survey of the Colony and also to superintend the formation establishment and management of a public museum and laboratory to form part of the property of the institution hereinafter mentioned and if required so to do to perform such other duties as are hereinafter mentioned with such salary not exceeding the sum of eight hundred pounds per annum as to the Governor in Council shall seem meet.

3. It shall also be lawful for the Governor from time to time to appoint such persons to assist in carrying out the said geological survey as he shall think fit.

4. It shall be the duty of the person appointed to superintend and carry out the said survey and if required by the Governor so to do from time to time to superintend the formation and establishment of any museum or laboratory intended to be established by any society incorporated with the institution hereinafter mentioned but the necessary travelling and other expenses of such person incident

to such superintendence shall be borne and defrayed by and out of the funds of the society establishing the said museum or laboratory and the same shall as nearly as possible be paid in advance.

5. On and after the passing of this Act and until the first day of November one thousand eight hundred and sixty-eight the Governor for the time being of the said Colony the Colonial Secretary for the time being of the said Colony and the Superintendent for the time being of the Province of Wellington and six other persons to be appointed after the passing of this Act by the Governor shall be a board of governors of an institution which shall be called " The New Zealand Institute " and they and their successors to be appointed as hereinafter mentioned together with the governors to be selected as hereinafter provided and the members for the time being of all and every society or societies hereafter to be incorporated with the said institute in such manner as is hereinafter provided for so long and such time as such several societies shall remain and continue to be incorporated with the said institute shall be and they are hereby declared to be one body corporate and politic in deed name and law by the name of " The New Zealand Institute " and that by the same name they shall have perpetual succession and a common seal and shall and may sue and be sued implead or be impleaded grant or receive and shall have power and authority to take and purchase and hold lands tenements and hereditaments to them their successors and assigns for the purposes hereinafter mentioned.

6. On the first day of November one thousand eight hundred and sixty-eight and on the first day of November in each succeeding year three members of the said board of governors (other than the Governor the Colonial Secretary and the Superintendent of the Province of Wellington respectively for the time being) who shall have been present the least number of times at the meetings of such board shall retire from office but shall be eligible for re-appointment and in case of an equality between two or more members of the said board in respect of the number of attendances of such members at the meetings of the said board then the retiring members shall be determined by lot and on the annual retirement of the said three members and in case of the death resignation or incapacity of any member or members the successors of such retiring members or of such members so dying resigning or becoming incapable shall be appointed by the Governor.

7. So long as not more than three separate societies shall have been incorporated with the said institute it shall be lawful for each such society annually in the month of November to elect one of its members to be a member of the board of governors during the ensuing year but so soon as more than three separate societies shall have been incorporated with the said institute then and thenceforward it shall be lawful for each separate society so incorporated annually in the month of October to appoint one of its members to vote in the election of governors and the several members so appointed shall elect three from among themselves to be members of the board of governors

during the ensuing year and the members so elected shall enjoy equal rights and powers with the governors appointed as hereinbefore first provided.

8. Any branch society may cease to be incorporated with the institute by not electing any governors pursuant to section seven of this Act.

9. It shall and may be lawful to and for any person or persons bodies politic or corporate society or societies their heirs and successors to give and deliver and to grant convey assure devise and bequeath to the use and benefit of or in trust for the said body corporate any messuages lands tenements rents annuities and hereditaments whatsoever and any library books maps prints fixtures goods chattels minerals specimens or other effects or articles whatsoever calculated for the formation of a museum all which messuages lands tenements rents annuities or hereditaments and all which library books maps prints fixtures goods chattels minerals specimens or effects as aforesaid the said body corporate are hereby authorised and enabled to receive accept and hold.

10. It shall particularly be lawful for all persons and bodies politic or corporate society or societies who may at the time of the passing of this Act or afterwards may have power so to do to give and deliver and to grant convey and assure to the use and benefit of or in trust for the said body corporate the land and buildings situated in the City of Wellington now used as the Colonial Museum with the laboratory and other buildings connected or used therewith together with all the rights members and appurtenances to the same belonging and all the books maps prints pictures goods chattels minerals specimens and other effects and articles now in and about the same all which said land buildings and hereditaments books maps prints pictures goods chattels minerals specimens and effects as aforesaid the said body corporate are hereby authorised and enabled to receive accept and hold.

11. The said board of governors for the time being of whom three shall be a quorum shall have full power and authority in the name of the said body corporate to receive pay apply and dispose of all such moneys as shall be annually granted to the said body corporate for building or other special purposes and may enter into all such contracts and do and transact all such other acts deeds matters or things as may be requisite or proper to be done in and about the renting or purchase of suitable lands and premises or the renting and hiring or erecting or completing of suitable halls reading-rooms lecture-rooms class-rooms and other buildings and for the reception and safe custody of the library and other effects of the said body corporate and for the formation and reception of a museum and laboratory and for all such other purposes as the said board of governors for the time being may decide to be required to carry into effect the objects of the said body corporate or of the several societies to be admitted into and incorporated therewith and shall also have power if they shall think fit upon application made by any other society or societies or body or bodies of persons associated for the

purpose of promoting any art or science or branch of knowledge or by any person duly authorized in accordance with the laws of such several societies or associations to make such application to admit and incorporate such persons so associated as part of the said New Zealand Institute upon the terms and in the manner to be set forth in the statutes and rules of the said institute so long as the members of the said societies or associations shall annually pay for the advancement of the objects arts or sciences for the promotion of which they are so severally associated such a sum as the bye-laws of each particular society shall from time to time define and fix and shall have been agreed upon between such several societies and the board of governors of the said body corporate and shall also have full power to make bye-laws for the regulation and disposal of the property of the said body corporate and for its more regular government and also to direct and order at what times in what manner and under what restrictions and conditions the several societies and associations at any time forming part of and incorporated in the said institute shall have and use the halls lecture-rooms class-rooms reading-rooms libraries museums and other public property of the said body corporate and such bye-laws terms restrictions and conditions or any of them from time to time shall and may rescind alter and vary and make others in their stead and also shall and may do manage transact and determine all such other acts deeds matters and things as shall to them appear necessary for effecting and carrying out of the purposes of this Act and of the said body corporate but so nevertheless that the same shall be in accordance with and not contrary to or subversive of any of the statutes and rules of the said body corporate and shall and may if they see fit delegate any of the powers and authorities vested in them to all or any of the committees of the several societies which may hereafter be incorporated with the said institute so as the same shall relate or apply to such societies respectively and shall also have power to appoint and remove any public officers of the said body corporate and from time to time to fix and determine the salary and emoluments to be paid to such officers and servants.

12. Whenever any society or societies shall have been incorporated with the said institute a general meeting of the said body corporate shall be holden annually on the third Monday in the month of January at such hour and at such place as shall from time to time be fixed by the said board of governors such general meeting to consist of not less than ten members of the said body corporate exclusive of any members of the said board of governors and that if a sufficient number of members of the said body corporate to form a meeting be not present within one hour of the time fixed for such meeting the said board of governors shall be empowered to adjourn the said meeting unto such time as they may appoint and that at such general meetings a report of the proceedings during the preceding year of the said body corporate and of the societies incorporated therewith shall be laid before the members of the said body corporate and that it shall be lawful for the members of the said

body corporate present at such meetings to make ordain and constitute such bye-laws constitutions and ordinances for the government of the affairs of the said body corporate as to the majority of such members shall seem meet and such bye-laws constitutions and ordinances to revoke change and alter and others to make in their stead. Provided always that such bye-laws constitutions and ordinances shall not be contrary or repugnant to any of the laws or customs of the Colony or to this Act or to any rules to be made by the Governor in Council as aforesaid. And provided also that no such bye-laws constitutions or ordinances or any bye-laws to be made or passed at any special general meeting as hereinafter provided shall be binding or have any force or effect until the same shall have been confirmed by the said board of governors.

13. Any three of the said governors of the said body corporate for the time being by giving one calendar month's notice in one or more newspapers published in those parts of the said Colony in which the said institute and any societies incorporated therewith shall severally be established and affixing a legible copy of such notice in a conspicuous place in the building occupied by the said body corporate may at any time convene a special general meeting of the said body corporate for the purpose of making or altering any bye-laws constitutions or ordinances of the said body corporate or of confirming or altering the proceedings of any annual or special meeting or for the transaction of any of the affairs and business of the said body corporate as occasion may require and that all such special meetings shall be in like manner holden and have the same powers in every respect as the annual general meetings hereinbefore provided.

14. In addition to the salary to be paid to the Superintendent of the Geological Survey to be fixed as hereinbefore mentioned there shall be yearly placed upon the estimates to be laid before the House of Representatives of the said Colony a sum of not less than five hundred pounds to be applied in the payment of the general current expenses of the said body corporate or of any of the several societies or associations incorporated therewith and otherwise for the promotion of the general objects of the said body corporate or of the special objects of any of the several societies to be incorporated therewith in such manner in all respects as to said board of governors for the time being shall seem fit and that every sum which shall be voted by the General Assembly of the said Colony for such purposes shall be received by such member of the said board of governors for the time being as shall have been appointed by the said board of governors to act as treasurer and carried to a separate account and that such treasurer shall be thereout required to pay and allow such sum or sums only as the said board of governors for the time being shall direct and require to be paid for all or any of the purposes herein mentioned provided always and it is hereby declared that the moneys so to be placed upon the estimates as aforesaid shall not be deemed to include the current expenses of the geological survey

of the said Colony which current expenses shall be fixed and appropriated in like manner as those of any other ordinary department of the Government of the said Colony.

15. It shall be lawful for the Governor in Council from time to time and at all times hereafter to make alter and amend all such rules and statutes as may be necessary for the regulation and management of the said institute and such rules and statutes shall be published in the *New Zealand Gazette*.

16. It shall be lawful for the said board of governors from time to time and at all times hereafter to frame and suggest such alterations or amendments in the rules to be made by the Governor in Council as aforesaid and that such alterations or amendments shall if approved by the Governor in Council come into force from and after such approval.

17. Every rule and statute to be made as aforesaid and every amendment thereof shall be laid upon the table of the Legislative Council and House of Representatives of the said Colony during their session for the space of ten days and if during that time the said rules or statutes or any alterations or amendments as the case may be be not objected to or disallowed by a resolution of the said Legislative Council or House of Representatives then and thenceforward the said rules and statutes or alterations or amendments as the case may be shall be deemed to be and shall be confirmed and shall possess the same power validity and authority in all respects as if they had been embodied in this Act provided always that no such rules or statutes or alterations or amendments shall be contrary to or subversive of the provisions contained in this Act itself.

18. This Act shall be deemed a public Act and shall commence and take effect from the passing thereof.

THE ROYAL SOCIETY OF NEW ZEALAND ACT, 1933

NEW ZEALAND.

ANALYSIS.

1933, No. 17.

An Act to abolish the New Zealand Institute and to constitute in lieu thereof a Body for the Promotion of Science, to be known as the Royal Society of New Zealand. [*6th December, 1933.*

Be it enacted by the General Assembly of New Zealand in Parliament asembled, and by the authority of the same, as follows:—

1. This Act may be cited as the Royal Society of New Zealand Act, 1933.

2. (i) The New Zealand Institute constituted by "The New Zealand Institute Act, 1908," is hereby abolished and the Board of Governors thereof is hereby dissolved.

(ii) There is hereby constituted as successor to the New Zealand Institute a body which, in accordance with the gracious approval of His Majesty heretofore duly given, shall be called the Royal Society of New Zealand (hereinafter referred to as the Society) and under that name shall be a body corporate with perpetual succession and a common seal, and shall be capable of holding real and personal property, and of doing and suffering all that bodies corporate may do and suffer.

3. The Society shall consist of the Auckland Institute, the Wellington Philosophical Society, the Philosophical Institute of Canterbury, the Otago Institute, the Hawke's Bay Philosophical Institute, and the Nelson Institute as member bodies, and such other bodies as may hereafter, in accordance with rules in that behalf made by the Council of the Society, be declared to be member bodies of the Society, together with the individual members for the time being of all such member bodies.

4. (i) There is hereby constituted a Council of the Society (hereinafter referred to as the Council) which shall consist of—

(a) The Minister for the time being in charge of the Department of Scientific and Industrial Research;

(b) Four members to be appointed by the Governor-General in Council, of whom two shall be appointed during the month of March in every year, the first of such appointments to be made in the month of March, nineteen hundred and thirty-four;

(c) Eight members to be appointed in the month of March, nineteen hundred and thirty-four, and in the same month in every alternate year thereafter, of whom two shall be appointed by the Auckland Institute, two by the Wellington Philosophical Society, two by the Philosophical Institute of Canterbury, and two by the Otago Institute.

(d) One member to be appointed by each of the other member bodies in the month of March, nineteen hundred and thirty-four, and in the same month in every alternate year thereafter;

(e) The President and Vice-President of the Society if not otherwise members of the Council.

(ii) The Council itself may from time to time if and when it thinks fit so to do appoint for a term not exceeding two years any fit person to be a member of the Council.

(iii) Pending appointments of members of the Council pursuant to paragraphs (b) to (d) respectively of sub-section one hereof and the last preceding sub-section, the members of the Board of Governors of the New Zealand Institute appointed under the corresponding provisions of section three of the New Zealand Institute Act, 1908, and in office immediately before the passing of this Act, shall for all purposes be deemed to be members of the Council and shall continue in office as follows:—

(a) Of the four members appointed by the Governor-General in Council the two longest in office without reappointment shall retire on the first appointment by the Governor-General in Council of two members under paragraph (b) of sub-section one hereof, and the other two shall retire on the second appointment of two members under that paragraph;

(b) The member appointed by the said Board of Governors shall retire on the expiration of the period for which he was so appointed.

(c) All the other members shall retire on the first appointments of members pursuant to paragraph (c) or paragraph (d) of sub-section one hereof, as the case may be, by the respective member bodies by which they were appointed to membership of the said Board of Governors.

5. (i) Of the members of the Council appointed under subsections one and two of section four of this Act—

(a) The members appointed by the Governor-General in Council in the month of March in any year shall retire on the appointment of other such members in the same month in the second year thereafter;

(b) The member or members appointed by any member body shall retire on the appointment of a successor or successors by that body;

(c) The member appointed by the Council shall retire on the expiration of the term for which he was appointed.

(ii) Every member retiring from office as aforesaid shall be eligible for reappointment.

6. (i) Any appointed member of the Council may at any time resign his office by writing addressed to the Council, and in such case, or in case of his death, the vacancy in the membership of the Council shall within three months from the date of such resignation or death be filled by appointment of some fit person by the authority that appointed the member whose office has become vacant, and if not filled within that time the vacancy shall be filled by the Council;

Provided that it shall not be necessary for the Council to fill a casual vacancy caused by the resignation or death of the member appointed by it under sub-section two of section four hereof.

(ii) Any person appointed to fill any such vacancy shall hold office only for the remainder of the term for which his predecessor was appointed.

7. (i) The Governor-General shall during his pleasure be the Honorary Patron of the Society.

(ii) At its first annual meeting held after the passing of this Act, and at every annual meeting held thereafter, the Council shall appoint some fit person to be President and some fit person to be Vice-President of the Society.

(iii) Each of such officers shall come into office at the close of the annual meeting at which he is appointed and hold office until his successor comes into office, and shall be eligible for reappointment.

(iv) Where by reason of death or resignation either of such offices becomes vacant the vacancy shall be filled by appointment by the Council of some fit person to hold office until the person appointed at the next annual meeting comes into office.

(v) The President, and in his absence or incapacity the Vice-President, shall, subject to direction by the Council, superintend and carry out all necessary work in connection with the affairs of the Society, and shall be the chairman of all meetings of the Society and the Council.

(vi) The persons holding office as President and Vice-President respectively of the New Zealand Institute immediately before the passing of this Act shall be deemed to be President and Vice-President of the Society until the persons first appointed to those offices under sub-section one of this section come into office.

8. (i) The Council may from time to time, as it sees fit, make arrangements for the holding of general meetings of members of the Society, for the reading of scientific papers, the delivery of lectures, and the promotion of science in New Zealand by any means that may appear desirable

(ii) An annual meeting of the Council shall be held in the month of May, nineteen hundred and thirty-four, and in the same month or the month of April in each year thereafter as the Council from time to time determines, at a time and place fixed by the Council, to deal with such matters as are required by this Act or any rules thereunder to be dealt with at the annual meeting, and such other matters as that meeting thinks fit. At each annual meeting the President shall present a report of the work of the Society for the year ended the thirty-first day of March then last past, and a statement of accounts (including a Receipts and Payments Account) duly audited

(iii) Ordinary meetings of the Council shall be held from time to time as the Council or the President directs

(iv) In the absence of both the President and the Vice-President from any meeting of the Society or the Council the members present shall elect one of their own number to be Chairman of that meeting

(v) At every meeting the Chairman shall have a deliberative vote, and, in case of an equality of votes, shall also have a casting vote.

9. (i) The Council shall have the control and management of the Society and of all property for the time being vested in the Society, and may dispose, in such manner as it thinks fit, of any grants, bequests, or gifts of books or specimens of any kind whatever made to the Society, and generally shall act for and on behalf of the Society.

(ii) The Council may from time to time appoint standing or special committees, and may relegate to such committees any matters for consideration, or inquiry, or management, or regulation; and may delegate to any such committee any of the powers or duties of the Council

(iii) The Council may from time to time appoint such officers and servants and pay to them such remuneration as it thinks fit.

(iv) The Council shall appoint the President or some other fit person to be Editor of the transactions of the Society.

(v) The Council may from time to time expend in such manner as it thinks fit for the promotion of science any funds of the Society not appropriated or held in trust for any special purpose.

10. The Council may from time to time elect any person who has rendered eminent services to science to be a Fellow or an honorary member of the Society, and may also from time to time make awards of medals or other prizes to persons deemed worthy of such awards by reason of any research, investigation, or other scientific work made or done by them.

11. (1) The Council may from time to time by resolution passed at any meeting thereof make rules not inconsistent with this Act for all or any of the following purposes, namely:—

(a) Governing the admission of scientific bodies as member bodies of the Society, and prescribing the conditions on which they may continue to be member bodies and the annual or other fees (if any) to be paid by member bodies.

(b) Regulating the proceedings of the Council and of committees and the conduct of meetings thereof respectively.

(c) Providing for the custody of the property of the Society, and the custody and use of the common seal of the Society.

(d) Prescribing the form and manner of keeping accounts of moneys of the Society.

(e) Prescribing the duties of officers and servants.

(f) The encouragement of research by members of the Society.

(g) Regulating the election and prescribing the privileges and duties of Fellows and honorary members of the Society and regulating the making of awards.

(h) Such other matters as may be necessary for duly carrying out the work of the Society or the Council.

(ii) Notice of every resolution proposed to be submitted to any meeting for the making, amendment, or revocation of any such rules as aforesaid shall be given to every member of the Council fourteen clear days before the day fixed for such meeting.

(iii) Every resolution making, amending, or revoking any such rules as aforesaid shall be published in the *Gazette*, and shall have force and effect as from the date of gazetting thereof or some later date to be specified in such resolution.

(iv) *Prima facie* evidence that any rule under this section has been duly made and remains in force may be given in all legal proceedings by the production of a copy of the *Gazette*, purporting to contain such rule or by the production of a copy of such rule purporting to be printed by the Government Printer.

12. The Minister of Finance shall, out of moneys appropriated by Parliament for the purpose, pay to the Council the sum of five hundred pounds in each financial year, commencing with the year beginning on the first day of April, nineteen hundred and thirty-four, to be applied in or towards payment of the general expenses of the Society.

13. On the passing of this Act all real and personal property of every description vested in the Board of Governors of the New Zealand Institute shall vest in the Society without conveyance or assignment for the estate and interest of the said Board therein, subject to all liabilities, charges, obligations, or trusts affecting

that property, and all the contracts, debts, and liabilities of the said Board shall become the contracts, debts, and liabilities of the Society.

14. Forthwith upon the gazetting of any resolution making, amending, or revoking any rules under this Act or the publication of any transactions, the Council shall transmit a copy thereof to the Minister for the time being in charge of the Department of Scientific and Industrial Research, who shall lay the same before Parliament, if then sitting, or, if not, then within twenty-one days after the commencement of the next ensuing session.

15. (i) The New Zealand Institute Act, 1908, the New Zealand Institute Amendment Act, 1930, section seven of the Finance Act, 1925, and section seven of the Finance Act, 1931 (No. 2) are hereby repealed.

(ii) With respect to those enactments the following provisions shall apply:—

(a) All appointments and other acts of authority which originated under any of the said enactments or any enactment thereby repealed, and are subsisting or in force on the commencement of this Act shall enure for the purposes of this Act as fully and effectually as if they had originated under the corresponding provisions of this Act, and accordingly shall, where necessary, be deemed to have so originated.

(b) All regulations made by the Board of Governors of the New Zealand Institute under any of the said enactments and in force immediately before the passing of this Act shall continue in force as rules under this Act until amended or revoked under this Act.

(c) All matters and proceedings commenced under any of the said enactments and pending or in progress on the commencement of this Act may be continued, completed, and enforced under this Act.

(iii) All references in any other Act to the New Zealand Institute or the Board of Governors, or the President or Vice-President thereof respectively, shall hereafter be deemed for all purposes to be and shall be read as references to the Society or the Council or the President or Vice-President of the Society, as the case may require.

Appendix B.

THE ROYAL SOCIETY OF NEW ZEALAND, 1935

ESTABLISHED UNDER AN ACT OF THE GENERAL ASSEMBLY OF NEW ZEALAND INTITULED THE NEW ZEALAND INSTITUTE ACT, 1867; RE-CONSTITUTED UNDER THE NEW ZEALAND INSTITUTE ACT, 1903, CONTINUED UNDER THE NEW ZEALAND INSTITUTE ACT, 1908; AND RECONSTITUTED UNDER THE ROYAL SOCIETY OF NEW ZEALAND ACT 1933.

PATRON

His Excellency the Governor-General.

COUNCIL.

EX OFFICIO.

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Wellington Philosophical Society .	Mr F R. Callaghan, Department of Scientific and Industrial Research, Sydney Street, Wellington.	10th June, 1868
Philosophical Institute of Canterbury . .	Mr L. W McCaskill, Teachers' Training College, Christchurch.	22nd October, 1868.
Otago Institute	Mr H. D. Skinner, Otago Museum, Dunedin.	18th October, 1869.
Hawke's Bay Branch of the Royal Society of New Zealand	Mr G. T. Railton, P.O. Box 160, Napier.	31st March, 1875.
Nelson Institute . ..	Mr O. B. Pemberton, Cawthron Institute, Nelson.	20th December, 1883.

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Fraser, Sir J. G., D.C.L., Trinity College, Cambridge	1920
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Rutherford of Nelson, Lord, D.Sc., F.R.S., F.R.S.N.Z., Newnham Cottage, Queen's Road, Cambridge, England	1904
Seward, Professor A. C., Sc.D., F.R.S., Botany School, Cambridge	1928
Woods, Henry, M.A., F.R.S., F.G.S., Sedgwick Museum, Cambridge	1920

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(See *New Zealand Gazette*, 20th November, 1919.)

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*Buck, P. H. (Te Rangi Hiroa), M.D., Ch.B. (N.Z.)	1925
*Cotton, Charles Andrew, D.Sc., A.O.S.M., F.G.S.	1921
Cunningham, Gordon Herriot, M.Sc., Ph.D.	1929
Denham, Henry George, M.A., M.Sc., D.Sc., Ph.Dd.	1933
*Evans, William Percival, M.A., Ph.D.	1930
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Adams, Dr C. E., Dominion Observatory, Kelburn, W.1.
Andersen, J. C., Turnbull Library, Wellington.
Cotton, Professor C. A., Victoria University College, Wellington, W.1.
Freeman, C J., 10 Washington Avenue, Brooklyn, S.W.2.
Garrow, Professor J. M. E., Nelson.
Gifford, A. C., 22 Chatsworth Road, Silverstream.
Hastie, Miss J. A., c/o Street and Co, 30 Cornhill, London. E.C.
Kidson, Dr E., Meteorological Office, Kelburn.
King, Mr L. C., Natal University College, Pietermaritzburg, South Africa.
Oliver, Dr W. R. B., Dominion Museum, Wellington.
Ongley, M., Geological Survey Office, Wellington.
Roy, R. B., Taita.

ANNUAL MEMBERS.

Adkin, G. L., Queen Street, Levin.
Allan, Dr H. H., Plant Research Station, Palmerston North.
Aston, B. C., Chemical Laboratory, Department of Agriculture, Wellington.
Baillie, H., 18 Fitzroy Street, Wellington, N.2.
Barnett, Dr M. A. F., Department of Scientific and Industrial Research, Wellington.
Beaumont, Dr J. H., 200 Willis Street, Wellington, C.2.
Beckett, Peter, Paraparaumu.
Beddie, A. D., 174 Hutt Road, Petone.
Bell, E. T. D., Featherston Street, Wellington, C.1.
Bell, Sir Francis, Featherston Street, Wellington, C.1.
Bennett, Francis, 41 Everest Street, Khandallah, N.5.
Berry, C. G. G., 31 Seaview Terrace, Northland, W.2.
Blair, David K., 13 Grey Street, Wellington, C.1.
Brandon, A. de B., Featherston Street, Wellington, C.1.
Callaghan, F. R., Dept. of Scientific and Industrial Research, Wellington.
Christeson, T. A., 4 Salisbury Terrace, Wellington, S.1.
Cockayne, A. H., Department of Agriculture, Wellington.
Cockroft, T., c/o Bank of New Zealand, Wellington.
Cook, C. W., Head Office, Customs Department, Wellington.
Coventry, Mrs H., 9 Mowbray Street, Wellington, C.1.
Crawford, A. D., G.P.O. Box 126, Wellington.
Croker, Mrs O. R., 17 Tamar Street, Island Bay, S 2.
Cromb, J. B., c/o Wellington Harbour Board, Wellington, C.1.

WELLINGTON PHILOSOPHICAL SOCIETY—ANNUAL MEMBERS (cont.)

Cumming, E. J. R., Land and Income Tax Department, Wellington.
Cunningham, Dr G. H., P.O. Box 442, Palmerston North.
Dalrymple, K. W., "Parewanui," Bulls.
Donovan, W., Dominion Laboratory, Wellington.
Dunn, L. R., Dominion Laboratory, Wellington.
Dymock, E. R., Box 193, Wellington.
Evans, Prof. W. P., 22 Kensington Street, Wellington, C.2.
Farquharson, C. H., Chemist, Tinakori Road, Wellington, N.1.
Ferguson, William, Marlborough Road, Silverstream.
Ferguson, W. D., North Terrace, Kelburn, W.1.
Florance, Prof. D. C. H., Victoria University College, Kelburn, W.1.
Forrester, J. H., Customs Department, Wellington.
Furkert, F. W., 58 Matai Road, Wellington, E.2.
Fyfe, H. E., Geological Survey Office, 156 The Terrace, Wellington.
Gavey, A., Public Works Department, Wellington.
Gibbs, A., 69 Tiber Street, Island Bay, S.2.
Gibbs, Dr H. E., 240 Willis Street, Wellington, C.2.
Gill, D. A., Pathological Laboratory, Wallaceville.
Good, F. W., Electric Light Department, Harris Street, Wellington, C.1.
Grange, L. I., Geological Survey Office, 156 The Terrace, Wellington.
Gray, J. D., 75 Grant Road, Wellington, N.1.
Grimmett, R. E. R., Chemical Laboratory, Department of Agriculture, Wellington.
Hamilton, Alexander, 16 Rimu Road, Kelburn, W.1.
Hamilton, William, Massey Agricultural College, Palmerston North.
Harty, Dr G. W., 14 Hill Street, Wellington, N.1.
Hayes, Captain L., 56 Boulcott Street, Wellington, C.1.
Heays, H. C., Head Office, Public Works Department, Wellington.
Hefford, A. E., Marine Department, Wellington.
Heine, Miss E. M., Dominion Museum, Wellington.
Henderson, Dr J., Geological Survey Office, 156 The Terrace, Wellington.
Hislop, T. G., Wellington College, Wellington, E.1.
Hopkirk, Dr C. S. M., Pathological Laboratory, Wallaceville.
Hudson, G. V., "Hill View," Messines Road, Karori, W.3.
Hunt, A. Leigh, Managing Director, Dominion Farmers' Institute, Wellington, C.1.
Jackson, P. M., 2 Resolution Street, Lyall Bay, E.3.
Joiner, W. A., Dominion Laboratory, Wellington.
Jones, A. Morris, 6 Raroa Road, Kelburn, W.1.
Kean, A., Department of Internal Affairs, Rotorua.
Kirk, Professor H. B., Victoria University College, Wellington, W.1.
Kirk, J. R., "Courtlands," 105 Majoribanks Street, Wellington.
Kissel, F. T. M., Public Works Department, Wellington.
Lawton, H., Krull Street, Vogeltown.
Levi, P., Stout Street, Wellington.
Lomas, J. S., Wellington College, Wellington.
Lomas, E. K., c/o Hawke's Bay Education Office, Napier.
Maclaurin, Dr J. S., Pitt Street, Wadestown.
Malden, H., 56 Penrose Street, Lower Hutt.
Martin, J. T., c/o Wright, Stephenson and Co., Wellington.
McDermott, J., c/o Chief Telegraph Engineer, Post and Telegraph Department, Wellington.
McInnes, E. H., Box 638, Wellington.
MacPherson, E. O., Geological Survey Office, 156 The Terrace, Wellington.
Marchbanks, J., Harbour Board, Wellington.
Marshall, Dr P., Petrological Laboratory, Pipitea Point, Wellington.
Marwick, Dr J., Geological Survey Office, 156 The Terrace, Wellington.
Marsden, Dr E., Department of Scientific and Industrial Research, Wellington.
Maxwell, E., Maramarunui, Opunake.
Mestayer, Miss M., Sydney Street West, Wellington.
Moir, Dr G. M., Veterinary Laboratory, Wallaceville.
Moore, G., Eparaima, via Masterton.
Moore, W. L., c/o Boving and Co., Hudart Parker Building, Wellington.
Morice, Dr C. G., 24a Hill Street, Wellington, N.1.
Morice, Miss I., 40 Wadestown Road, Wellington.
Neill, W. T., 40 Glen Road, Kelburn.
Newnham, W. L., Inspecting Engineer, Public Works Department, Wellington.
Norman, E. P., Town Clerk, Town Hall, Wellington.
Palmer, C. E., St. John's Hostel, Willis Street, Wellington, C.2.

WELLINGTON PHILOSOPHICAL SOCIETY—ANNUAL MEMBERS *(cont.)*

ayne, A. H., Wellington College, Wellington, E.1.
eddie, G. A., Victoria University College, Wellington, W.1.
hillipps, W. J., Dominion Museum, Wellington.
lank, C. S., Telegraph Engineering Department, G.P.O., Wellington.
igott, Miss E., Victoria University College, Wellington, W.1.
ilcher, E. G., 225 Wellington Terrace, Wellington.
ope, F. S., 34 Kelburn Parade, Wellington.
owell, R., 3 Courtenay Place, Wellington, C.3.
owles, E. R., 34 Wesley Road, Wellington.
ands, Henry, Wellington Gas Co., Miramar.
eakes, Dr C. J., Department of Agriculture, Wellington.
ichards, Dr W., 180 Willis Street, Wellington. C.2.
cott, Rev. D. D., The Manse, Khandallah.
eed, A. J., Clark Street. Khandallah.
eelye, F. T., Dominion Laboratory, Wellington.
hirtcliffe, G., P.O. Box 438, Wellington.
horland, F. B., Chemical Laboratory Department of Agriculture, Wellington.
immers, R. G., Meteorological Office, Wellington.
ladden, H., Woburn Road, Lower Hutt.
mith, C. M., State Forest Service, Wellington.
mith, H. L. C., Railway Department, Wellington.
mith, J. R., Radio Broadcasting Board, Featherston Street, Wellington, C.1.
pencer, Dr F. M., Kelvin Chambers, The Terrace, Wellington.
Sunley, R. M., Audit Department, Wellington.
Taylor, N. H., Geological Survey Office, Wellington.
Taylor, Dr R. M. S., Dental Clinic, Government Buildings, Wellington.
Tennent, Dr A., 25 Moxham Avenue, Hataitai, E.2.
Thompson, J. B., 7a Dufferin Street, Wellington.
Thomson, I. L., Dominion Observatory, Wellington.
Thomson, Miss M., Victoria University College, Wellington.
Thomson, P., Solicitor, Stratford.
Thomson, Dr W. M., Hawera.
Tombs, H. H., Burnell Avenue, Wellington.
Treadwell, C. H., Maritime Building, Custom House Quay, Wellington.
Vickerman, H., Box 920, Wellington.
Ward, W. C., State Forest Service, Wellington.
Webster, H. A., c/o Begg and Co., Wellington.
Widdop, F. C., 98 Upland Road, Kelburn.
White, P., Dominion Laboratory, Wellington.
Wild, G. V., Education Department, Wellington.
Wilkinson, A. S., Caretaker, Kapiti Island.
Williamson, J. H., Geological Survey Office, 156 The Terrace, Wellington.
Wilson, S. H. J., Dominion Laboratory, Wellington.
Wilton, C. L., Tane, Ekatahuna.
Yeates, Dr J. S., Massey Agricultural College, Palmerston North.
Tyndall, A., Mines Department, Wellington.

ASSOCIATES.

Astronomical Section.

arnes, J. C., Taita.
utterton, M. S., 37 Palmer Street, Wellington.
rust, A. G. C., Meteorological Office, Wellington.
Hutchings, J. W., 14 Sussex Street, Wellington.
Jelley, A. M., 38 Owen Street, Newtown, S.1.
Richardson, Miss C. L., 18 Newman Terrace, Wellington, N.1.

Biological Section.

all, E. V., "Evening Post," Wellington.
ocking, Mr G. H., State Forest Service, Wellington.
cott, R. D., 96 Moxham Avenue, Hataitai, E.2.
Sutherland, Miss M., Dominion Museum, Wellington.
Young, Mr M. W., Marine Department, Wellington.

Technological Section.

Barnicoat, C. R., Dairy Research Institute, P.O. Box 367, Palmerston North.
Beach, C. H., City Engineer's Office, Wellington, C.1.
Hartridge, E. C., c/o J. J. Niven and Co., Taranaki Street, Wellington.
Hodge, W. J., c/o A. and T. Burt, 83-87 Courtenay Place, Wellington, C.3.
McKillop, E. R., 87 Brougham Street Wellington.
Simpson, E. C., 14 Marshall Street Karori.
Symington, I. D., c/o A and T. Burt 83-87 Courtenay Place, Wellington, C.3

PHILOSOPHICAL INSTITUTE OF CANTERBURY.

LIST OF MEMBERS AT OCTOBER 31, 1934.

(* Denotes a Life Member.)

Acland, Sir Hugh, 51 Brown's Road Christchurch.
Alexander, Professor R. E., C.M.G., Canterbury Agricultural College, Lincoln.
Allan, R. S., M.Sc., Ph.D., F.G.S., Canterbury College, Christchurch.
Anderson, D. W., B.Sc., West Christchurch High School, Christchurch.
Baird, H. F., M.Sc., Magnetic Observatory, Christchurch.
Bamford, P. G., B.E., Canterbury College, Christchurch
Banfield, H., 94 St Martin's Road, Christchurch.
Barnett, W. J. F., 35 Hardwicke Street, Sumner.
Beagley, J. W., M.Sc., Magnetic Observatory, Christchurch.
Beattie, G. C., M.Sc., High School, Rangiora.
*Beaven, A. W., c/o Andrews and Beaven, Moorhouse Avenue, Christchurch.
Belton, F. J. W., c/o Gas Company, Christchurch
Bennett, E. W., M.Sc., University of Western Australia, Perth, W.A
Berry, R. E., 165 Manchester Street, Christchurch.
*Biltcliff, G. S. A., 11 Clyde Road, Riccarton.
Black, H. B., 28 Winchester Street, Christchurch.
Booth, G. T., 242 Papanui Road, Christchurch.
Borrie, Dr F. J., 236 Hereford Street, Christchurch.
Bowker, George, 177 Stafford Street, Timaru.
Bradley, Orton, Charteris Bay.
Brittin, Guy, F.E.S., High Street, Motueka.
Brown, Professor Macmillan, M.A., LL.D., F.R.S.N.Z., Holmbank, Cashmere.
Bryden, William, M.Sc., Ph.D., Technical College, Christchurch.
Buchanan, J. D. H., 300 Otipua Road, Timaru.
Burnett, T. D., M.P., Cave, South Canterbury.
Calder, J. W., M.Sc., B.Ag., Canterbury Agricultural College, Lincoln
Calvert, G. G., A.M.Inst.C.E., Canterbury College, Christchurch
Campbell, J. W., Dental Officer, Mental Hospital, Tokanui, Te Awamutu.
Carlyle, T., "Sun" Office, Christchurch.
Carrington, A. H., c/o "Christchurch Times," Christchurch.
Cartwright, F., 19 Andrew's Square, Christchurch.
Chairman, New Plymouth Public Library Committee, New Plymouth.
Clark, W. H., 100 Bealey Avenue, Christchurch.
Coates, C. Carlyon, 134 Hereford Street, Christchurch.
Coles, W. R., 358 Gloucester Street, Christchurch.
Collins, C. W., M.A., Librarian, Canterbury College, Christchurch.
Cooper, S. A., B.Sc., District High School, Fairlie.
Cox, P. T., M.Sc., c/o Anglo-Persian Oil Coy., Britannia House, Finsbury Circus, London, E.C.2.
Cull, Professor J. E. L., B.Sc.Eng., A.M.I.M.E., Canterbury College, Christchurch.
Deans, John, Kirkstyle, Coalgate.
Denham, Professor H. G., M.A., D.Sc., Ph.D., F.I.C., F.R.S.N.Z., F.N.Z.I.C., Canterbury College, Christchurch.
Dorrien-Smith, Major A. A., D.S.O., Tresco Abbey, Scilly, England.
Drummond, James, F.L.S., F.Z.S., c/o "Christchurch Times," Christchurch.
Fairbairn, Miss E., M.A., Girls' High School, Christchurch.
Farr, Professor C. Coleridge, D.Sc., F.P.S.L., F.R.S.N.Z., F.R.S., Canterbury College, Christchurch.
Fitzgerald, J. S., M.Sc., Canterbury College, Christchurch.
Flay, A. H., B.Sc., M.Ag.Sc., Canterbury Agricultural College, Lincoln.
Florance, Miss E., 117 Caledonian Road, Christchurch.

PHILOSOPHICAL INSTITUTE OF CANTERBURY—MEMBERS *(cont.)*

Flower, A. E., M.A., M.Sc., Christ's College, Christchurch.
Foweraker, C. E., M.A., F.L.S., Canterbury College, Christchurch.
Frankel, O. H., Ph.D., Canterbury Agricultural College, Lincoln.
Franklin, M. C., M.Sc., Ph.D., Canterbury Agricultural College, Lincoln.
Fry, Sidney A. A., 15 Bellevue Avenue, Christchurch.
Galbraith, A. R., City Engineer, Christchurch.
Gale, F. H. D., c/o "Sun" Office, Christchurch.
Gilling, C. D., District High School, Fairlie.
Gilling, W. O. R., M.Sc., c/o Gas Coy., Moorhouse Avenue, Christchurch.
Glover, P. W., B.Sc., F.R.A.S., Apia, Samoa.
Godby, Mrs M. D., 5 Jackson's Road, Fendalton, Christchurch.
Godby, M. H., M.A., B.Sc., 176 Hereford Street, Christchurch.
Gower, S. W., Tinwald School, Ashburton.
Graham, Chas. H. E., 26 Gordon Avenue, Christchurch.
Grigg, F. J. T., M.Sc., F.I.C., Government Analyst, Government Buildings, Christchurch.
Guthrie, Dr John, 184 Armagh Street, Christchurch.
Hall, G., Hororata.
Hamilton, Miss A., B.Sc., 75 Withell's Road, Upper Riccarton, Christchurch.
Haynes, E. J., F.Z.S., Canterbury Museum, Christchurch.
Helson, G. A. H., M.Sc., 49 Malcolm Avenue, Christchurch.
Herriott, Miss E. M., M.A., St. Andrew's Square, Christchurch.
Hight, Professor J., M.A., Litt.D., C.M.G., Canterbury College, Chirstchurch.
*Hilgendorf, Professor F. W., M.A., D.Sc., F.R.S.N.Z., Canterbury Agricultural College, Lincoln.
Hitchcock, E., Municipal Electricity Department, Christchurch.
Hogg, E. G., M.A., F.R.A.S., 68 Hackthorne Road, Christchurch.
Hullett, E. W., M.Sc., c/o Wheat Research Institute, Hereford Street, Christchurch.
Hutchinson, F. E., B.Sc.F., c/o Department of Scientific and Industrial Research, Melbourne, Victoria.
Ironside, Miss A. F., M.A., Teachers' Training College, Christchurch.
Jameson, J. O., 152 Hereford Street, Christchurch.
Jamieson, W. G., Deans' Avenue, Lower Riccarton, Christchurch.
Jobberns, G., M.A., B.Sc., Teachers Training College, Christchurch.
*Kidson, E., M.A., D.Sc., F.R.S.N.Z., Dominion Meteorologist, Wellington.
Kitson, H., 37 Waiwetu Street, Fendalton, Christchurch.
Laing, R. M., M.A., B.Sc., F.R.S.N.Z., 37 Macmillan Avenue, Cashmere, Christchurch.
Laing, H. W., 146 St. Martin's Road, Opawa, Christchurch.
Lancaster, G. J., M.A., M.Sc., Boys High School, Christchurch.
Lawn, G., M.A., Canterbury College, Christchurch.
Leslie, A., M.R.C.V.S., Canterbury Agricultural College, Lincoln
Lindsay, Stuart, 18 Sydney Street, Spreydon, Christchurch.
Macleod, D. B., M.A., D.Sc., Canterbury College, Christchurch.
Maling, P. B., M.Sc., Canterbury College, Christchurch.
Mason, C. W. G., M.Sc., c/o Gas Coy., Moorhouse Avenue, Christchurch.
Mazey, G. A., 57 Fitzgerald Avenue, Christchurch.
Milligan, Dr R. R. D., A.M.P. Buildings, Cathedral Square, Christchurch.
Monro, F. R., St. Andrew's Square, Christchurch.
Morrison, L., B.Sc., Canterbury College, Christchurch.
Murray, Miss F. B., M.A., Ph.D., c/o High Commissioner for New Zealand, 415 The Strand, London, W.C.2.
McCaskill, L. W., M.Ag.Sc., Teachers Training College, Christchurch.
McCombs, T. H., M.Sc., Technical College, Auckland.
McGillivray, R., F.L.S., c/o Agricultural Department, Christchurch.
McKay, Dr W., 45 Guinness Street, Greymouth.
Nairn, R., Lincoln Road, Addington.
Oliver, F. S., Yanga Station, Balranald, N.S.W.
Ollivier, C. M., St. Martins, Christchurch
Packer, J., M.Sc., D.I.C., F.N.Z.I.C., Canterbury College, Christchurch.
Page, R. O., D.Sc., F.N.Z.I.C., 85 May's Road, Christchurch.
Page, S., B.Sc., 85 May's Road, Christchurch.
Pairman, Dr J. C., 21 Latimer Square, Christchurch.
Pairman, Dr T. W., "Moat Knowe," Governor's Bay.
Parrott, A. W., Canterbury College, Christchurch.
Percival, Professor E., B.Sc., N.D.A., Canterbury College, Christchurch.
Powell, Professor P. H., M.Sc., Canterbury College, Christchurch.

PHILOSOPHICAL INSTITUTE OF CANTERBURY—MEMBERS *(cont.)*

Rendle, C. A., c/o Chas Begg & Coy., Manners Street, Wellington.
Rhodes, J. H., 176 Hereford Street, Christchurch.
Ridley, S. G., 174 Otipua Road, Timaru.
Rhodes, Hon. Sir R. Heaton, Tai Tapu.
Roberts, F. K., c/o Public Works Department, Karamea.
Robinson, W. F., F.R.G.S., Canterbury College, Christchurch.
Rogers, M. N., M.Sc., Boys' High School, Christchurch.
Ruddle, L. W., 124 Stapleton's Road, Richmond, Christchurch
Saddler, Professor W., M.A., D.Sc., B.A. (Cantab.), F.R S. (Edin.) Canterbury College, Christchurch.
Scott, M. J., B.A., B.Sc, A I.C., Canterbury Agricultural College, Lincoln.
Shelley, Professor J., M A., Canterbury College, Christchurch.
*Simpson, Dr W. H., M D., cnr Papanui Road and Heaton Street, Christchurch.
Sims, A., M.A., c/o Sims, Cooper and Co., Hereford Street, Christchurch.
Skey, H. F., M.Sc., Magnetic Observatory, Christchurch.
Speight, Professor R., M.A., M.Sc., F.G.S., F.R.S.N.Z., Canterbury Museum, Christchurch.
Stead, E. F., Ilam., Riccarton. Christchurch.
Stokell, G., Prebbleton.
Steele, Professor S., B.Sc., (Mech. Eng.) Canterbury College, Christchurch.
Strachan, J. E., M.A., B.Sc., High School, Rangiora.
Stone, T., c/o "Christchurch Times," Christchurch.
Symes, Langford P., Paparoa Street Christchurch.
Taylor, G. J., 440 Madras Street, Christchurch.
Telford, Dr T. F., Government Buildings Christchurch.
Turner, H. S. E., 36 Brown's Road Christchurch
Vangioni, L. J., Akaroa.
Waller, F. D., B.A., 91 Papanui Road Christchurch.
Waller, R. D., Jolie Street, Akaroa.
West, H. E., Wheat Research Institute Hereford Street, Christchurch.
Whetter, Dr J. P., 211 Gloucester Street Christchurch
Widdowson, Dr H. L., 4 Oxford Terrace Christchurch.
Wilding, F. C., c/o Messrs Wilding and Acland, Hereford Street, Christchurch
Wood, W. H. J., 18 Balfour Terrace Christchurch.

OTAGO INSTITUTE.

LIST OF MEMBERS FOR 1934.

(* Denotes a Life Member.)

Adams, Professor T. D., M.A., Otago University.
Alexander, J. G., 120 Cliffs Road, St. Clair.
*Allen, Sir James, Clyde Street, Dunedin.
Anderson, J. G., High School, Balclutha.
Anderson, W. D., 32 Lynwood Avenue, Dunottar.
Anderson, Miss A. C., Macandrew Bay.
Andrew, Dr A. R., D.Sc, F.G.S., A.O.S.M., Mining School, Otago University.
Arras, G. C., 39 Brighton Street, Kaikorai.
Balk, O., 13 Driver Street, Maori Hill.
*Barnett, Sir L. E., Hampden.
Bathgate, Dr W. J., 84 Clyde Street, Dunedin.
Begg, J. C., F.R.A.S., Fifield Street, Roslyn.
Begg, Mrs A. C., 31 Ross Street, Roslyn.
Begg, Alex., 43 Ross Street, Roslyn.
Begg, Dr Andrew, Cancer Research Department, Medical School, Otago University.
Begg, Mrs L. H. L., 1 Claremont Street, Dunottar.
Bell, Professor R. J. T., M.A., D.Sc., Otago University.
*Benham, Professor W. B., D.Sc., M.A., F.R.S., F.N.Z.Inst., Otago University Museum
Benson, Professor W. N., D.Sc., B.A., F.G.S., F.R.G.S., Otago University.
Birrell, W. J., c/o Robin and Co., cnr Castle and Hanover Streets, Dunedin.
Beaumont, G. M., City Engineer's Office, Dunedin.
Black, James, 164 Crawford Street, Dunedin.
Bleakley, M., M.Sc., Biology Department, Otago University.
Borrie, Dr W. H., M.B., 226 High Street, Dunedin.
Bowbyes Miss A. M., Home Science Department, Otago University.
Bowron, G. W., 424 George Street, Dunedin.
Brasch, H., 99 London Street, Dunedin
Brookfield, Dr C. L., 18 Fifield Street, Roslyn.
Brown, A. T., 411 Princes Street, Dunedin.
Browne, R. A. S., c/o Post Office, Morrinsville.
Butler, J. G., c/o Westport Coal Co., Dunedin.
Carter, C. L., M.Sc., A.I.C., Otago University.
*Chapman, Sir F. R., 28 Eccleston Hill, Wellington.

Otago Institute—Members *(cont.)*

Chisman, A. J., Chemistry Department, Otago University.
*Dawson, Hugh, c/o Southern Cross Insurance, 107 High Street, Dunedin.
Davies, O. V., 109 Princes Street, Dunedin.
Dodds, Dr R. B., D.D.S., Dental School, Otago University.
Drew, W. A. H., City Engineer's Office, Town Hall, Dunedin.
Dunning, J. A., 16 Passmore Crescent, Maori Hill.
*Fels, W., 84 London Street, Dunedin.
*Ferguson, Dr Sir H. L., C.M.G., M.A., F.R.C.S.I., "Wychwood," Musselburgh Rise.
Ferguson, H. H., M.A., Otago University.
Findlay, Dr J N., M.A., Ph.D., Otago University.
Finlay, Dr H. J., 10 Pine Hill Terrace, Dunedin.
Fisher, Mrs A., M.Sc., Home Science Department, Otago University.
*Fitchett, Dr F. W. B., M.D., 8 Pitt Street, Dunedin.
Focken, Dr C. M., B.M.E., B.Sc., Physics Department, Otago University.
Fraser, Miss J., 165 Maitland Street, Dunedin.
Frye, Chas., 85 Neville Street, Caversham.
Fyfe, Miss M. L., M.Sc., Biology Department, Otago University.
Galway, Mrs V. E., 150 Highgate, Roslyn.
Gardner, W., Signwriter, 161a George Street.
Gardner, R., M.Sc., F.I.C., Dowling Street, Dunedin.
*Gilkison, R., 29 Highgate, Roslyn.
Graham, D., 718 King Street, Dunedin.
Gregory, Dr E., M.H.Sc., Home Science Department, Otago University.
Guthrie, H. J., 426 Moray Place East, Dunedin.
Hanlon, A. C., Moray Place, Dunedin.
Henderson, M. C., Town Hall, Dunedin.
Hercus, Professor C. E., M.D., B.D.S., D.P.H., Medical School, King Street, Dunedin.
Hobbs, L. J., Newington Avenue, Dunedin.
Holloway, Rev. J. E., D.Sc., F.N.Z.Inst., Museum, King Street, Dunedin.
Hobbs, W. H. B., Leckhampton Court, Caversham.
Howard B., Otago Boys' High School, Dunedin.
*Howes, W. G., F.E.S., 432 George Street, Dunedin.
*Howes, Miss Edith, Rawhiti Street, Sunshine, Dunedin.
Hunter, H., Medical School, King Street, Dunedin.
Hutton, C. O., 10 Hereford Street, Roslyn.
Hutton, Miss T., 10 Hereford Street Roslyn.
Inglis, Professor J. K. H., M.A., D.Sc. F.I.C., Otago University.
Irwin, Dr Wyn, Medical School, King Street, Dunedin.
Jack, Professor R., M.A., D.Sc., Ph.D. Otago University.
Joachim, Miss M. E., 4 Beaumont Road Mornington.
Johnson, S., 67 Warrender Street.
Jones, Dr D. W. Carmalt, M.A., M.D. F.R.C.P., High Street, Dunedin.
Kaye, William T. O., Forfar Street Mosgiel.
Kirk, R., c/o Geo. Kirk and Co., Dunedin.
*McCurdie, W. D. R., Borough Engineer Te Awamutu.
McGeorge, A. C., 56 Highgate, Roslyn.
McGeorge, E. G., Stock Exchange Buildings, Dunedin.
McGeorge, J. C., 96 London Street, Dunedin.
*McKellar, Dr T. G., Pitt Street, Dunedin.
MacLachlan, R. R. C., 742 King Street Dunedin.
Macky, Dr W. A., Physics Department Otago University.
Mackie, J. B., Mining School, Otago University.
*Malcolm, Professor J., M.D., Medical School, King Street, Dunedin.
Mandeno, H., N.Z. Express Co.'s Buildings, Crawford Street, Dunedin.
Marton, W., B.Sc., Borough School, Blenheim.
Meenan, J., 79 Cargill Street, Dunedin.
Merrington, Dev. Dr E. N., Knox College, Opoho.
*Milnes, J. W., 39 Lees Street, Dunedin.
*Moore, Dr S. A., Public Trust Buildings, Moray Place.
*Morrell, W. J., M.A., 230 Forbury Road, St. Clair.
Mullin, Dr W. J., 16 Maheno Street, Dunedin.
Mullin, Miss K., 16 Maheno Street, Dunedin.
Neale, G. H., 16 Pine Hill Terrace, Dunedin.
Nesbitt, A., c/o Telephone Exchange, Dunedin.
Newlands, Dr W., F.R.C.S., 24 London Street, Dunedin.
Niven, James, M.A., M.Sc., 34 Begg Street, Dunedin.
Orton, A. A., B.A., M.Sc., Otago University.
Paape, J. M., Grand Hotel, High Street, Dunedin.

OTAGO INSTITUTE—MEMBERS *(cont.)*

Paterson, A. S., 9 Alva Street, Dunedin.
Park, Professor J., F.G.S., F.N.Z.Inst., M.Inst.M.M., 23 Arawa Street, Anderson's Bay.
Park, Mrs J., 23 Arawa Street, Anderson's Bay.
Price, W. H., c/o Donald Reid and Co., Vogel Street, Dunedin.
Reid, Miss F., 79 Stafford Street, Dunedin.
Reid, Miss N., 79 Stafford Street, Dunedin.
Ritchie, Dr I. R., M.R.C.S., L.R.C.P., Public Health Department, Dunedin.
Roberts, E. F., Roberts' Buildings, Stuart Street, Dunedin.
Robertson, J. R., 47 Highgate, Roslyn.
Ross, T. C., Claremont Street, Donottar
Routledge, W. R., 40 Norfolk Street, St Clair.
Russell, R. Scott, M.Sc., 214 Highgate, Roslyn.
Sargood, Sir Percy R., "Marinoto," Newington, Dunedin.
Shacklock, J. B., Bayfield, Anderson's Bay.
Simpson, George, 69 Belgrave Crescent, Roslyn
Skinner, H. D., M.A., F.N.Z.Inst., Otago University Museum, King Street, Dunedin.
Smith, C. S., "Evening Star" Office, Dunedin.
Smith, H. McD., Edinburgh House, Dunedin.
Smith, Miss M., 409 Clyde Street, Dunedin.
Somerville, T., Coulls, Somerville, Wilkie, Dunedin.
Stark, James, c/o Kempthorne, Prosser and Co., Ltd., Dunedin.
Stewart, R. T., 21 Gamma Street, Roslyn.
Stewart, Hon. W. Downie, M.P., LL.B., 11 Heriot Row, Dunedin
Strong, Professor, A. G., B.Sc., Home Science Department, Otago University.
Teviotdale, D., Museum, King Street, Dunedin.
Thomson, G. W., 167 Signal Hill Road, Opoho.
Thomson, J. S., c/o Thomson and Co., Police Street, Dunedin.
Thomson, W. A., Ferntree House, 78 Halfway Bush, Dunedin.
Thomson, G. S., B.Sc., 99 Eglinton Road Mornington.
Tily, H. S., B.Sc., Custom House, Dunedin..
Turnbull, Miss M. I., M.A., Signal Hill Road, Opoho.
Turner, F. J., D.Sc., F.G.S, Geology Department, Otago University.
Uttley, Dr G., Southland Boys' High School, Invercargill.
Watt, Dr M. N., M B., Ch B., Medical School, Dunedin.
Webber, C. E. R., c/o Trustees Executors and Agency Co., Dunedin
*White, Professor D. R., M.A., 83 St David Street, Dunedin.
White, J. Renfrew, F R C.S., 456 George Street, Dunedin.
Wilkinson, H. K., 33 Royal Terrace, Dunedin.
Williams, J., B.Sc., F.C.S., Otago Boys High School, Dunedin.
Williams, W. J., City Engineer's Office Town Hall, Dunedin.

Also twenty-six Associate Members.

NELSON PHILOSOPHICAL SOCIETY.

MEMBERS FOR YEAR ENDING SEPTEMBER 30, 1934

Askew, Dr H. O., Cawthron Institute, Nelson.
Bartel, J. G., Seymour Avenue, Nelson
Baigent, L., Waimea Street, Nelson.
Bett, Dr F. A., Trafalgar Street, Nelson.
Bruce, J., Britannia Heights, Nelson.
Clark, A. F., Cawthron Institute, Nelson.
Curtis, Dr K. M., Cawthron Institute, Nelson.
Davies, W. C., Cawthron Institute, Nelson.
Duncan, H. R., Hardy Street, Nelson.
Dumbleton, L. J., Cawthron Institute, Nelson.
Easterfield, Professor, T. H., Bronte Street, Nelson.
Field, T. A. H., Hardy Street, Nelson.
Foster, F. W., Forestry Department, Nelson.
Garrow, Prof. J. M. E., Nile Street, Nel-
Gibbs, F. G., Collingwood Street, Nelson
Glasgow J., Stoke, Nelson.
Gourlay, E. S., Cawthron Institute, Nelson.
Jamieson Dr J. P. S., Hardy Street, Nelson.
Johnston, Dr W. D. S, Hardy Street Nelson.
Kidson, Miss E. B., Cawthron Institute Nelson.
Knapp, F. V., Alfred Street, Nelson.
McKay, J. G., Nelson College, Nelson.
Miller, Dr D., Cawthron Institute, Nelson.
Moncrieff, Mrs P., Port Nelson.
Morley, E. L., Alfred Street, Nelson.
Pemberton, O. B., Cawthron Institute Nelson.
Rigg T., Cawthron Institute, Nelson.
Tennant, J. S., Tahunanui.

ROYAL SOCIETY OF NEW ZEALAND, HAWKE'S BAY BRANCH.

LIST OF MEMBERS FOR 1934.

(* Denotes a Life Member.)

Elected.
1922—Absolom, Mrs J. H., Rissington.
1922—Absolom, J. Archer, Rissington.
1927—Armstrong, Dr J. S., Lake Taupo.
1899—Asher, Rev. J. A., Napier.
1934—Barnard, W. E., Napier.
1928—Barnett, Dr H., Napier.
1925—Beck, W. H., Napier.
1923—Berry, Dr J. A., Napier.
1934—Bestall, L. D., Napier.
1928—Brocklehurst, Very Rev. Dean, Napier.
1930—Chambers, Hugh C., Havelock North.
1882—Chambers, John, Havelock North.
1923—Chambers, Mason, Havelock North.
1927—Chapman, Hector, Napier.
1920—Clapcott, G. F., Napier.
1925—Clark, Dr Arthur, Napier.
1919—Clark, Thomas P., Eskdale.
1934—Corner, Frank, Napier.
1930—Cornford, Peter, Napier.
1933—Coe, E., Napier.
1933—Cornford, J. R., Napier.
1930—Cunningham, Miss J., Napier.
1893—Dinwiddie, W., Napier.
1929—Douglas, Charles, Napier.
1898—Duncan, R. J., Napier.
1907—Edgar, Dr J. J., Napier.
1913—Edmundson, J. H., Napier.
1934—Edwards, W. B., Napier.
1932—Foster, R. C. S., Napier.
1933—Foster, W. T., Napier.
1927—Geddis, Trevor M., Napier.
1928—Gilray, Dr T., Napier.
1923—Gleadow, J. E., Napier.
1906—Guthrie-Smith, W. H., Tutira, F.R.S.N.Z.
1899—Harding, J. W., Waipukurau.
1929—Hay, J. A. L., Napier.
1928—Herrick, Miss R., Napier.
1897—*Hislop, James, Napier.
1932—Hole, Geoffrey, Napier.
1931—Hudson, G. V., Wellington.

Elected.
1928—Husheer, G., Napier.
1902—Hutchinson, F., Rissington.
1931—Inglis, R., Napier.
1902—Large, Harold, Napier.
1906—Leahy, Dr J. P. D., Napier.
1906—Lindauer, V. William, Woodville.
1900—Lowry, T. H., Hastings.
1934—Lusk, Hugh B., Napier.
1930—MacKay, W. N. J., Napier.
1926—Martin, A. L., Napier.
1932—Melbye, C., Napier.
1886—*Moore, Dr T. C., Napier.
1930—Morling, J., Napier.
1923—*Ormond, Frank, Napier.
1884—Ormond, George C., Wairoa.
1933—Owen, R. J., Napier.
1918—Pallot, Alfred G., Napier.
1932—Pegram, J., Napier.
1919—Pallot, Mrs W. J., Napier.
1916—Pollock, C. F. H., Napier.
1933—Peel, J. D., Napier.
1934—Pollock, Joan H., Napier.
1930—Railton, G. T., Napier.
1922—Sainsbury, G. O. K., Wairoa.
1892—*Smith, H. J., England.
1927—Stewart, W. B., Napier.
1928—Tattersall, J., Napier.
1926—Thomas, C. L., Napier.
1930—Thomas, Owen L., Napier.
1910—Thomson, J. P., Napier.
1930—Twigg, W. D., Napier.
1922—Waterworth, Dr G., Napier.
1929—Wattie, A. J., Napier.
1932—Webb, P. E., Napier.
1924—West, E. S., Napier.
1925—White, William, Napier.
1934—White, W. J. O., Napier.
1927—Willan, T. J., Hastings.
1928—Williams, D. G., Clive.
1901—Williams, Right Rev. Bishop, Napier, F.R.S.N.Z.
1933—Wood, W. G., Napier.

Appendix C.

SERIAL PUBLICATIONS RECEIVED BY THE LIBRARY OF THE ROYAL SOCIETY OF NEW ZEALAND.

New Zealand.

Auckland Institute and Museum: *Records.*
Auckland University College: *Calendar.*
Canterbury Museum: *Records.*
Cawthron Institute: *Publications.*
Department of Agriculture: *Journal, Bulletins.*
Department of Scientific and Industrial Research: *Bulletins.*
Dominion Museum: *Monographs, Bulletins.*
Geological Survey: *Bulletins, Annual Reports.*
Journal of Science and Technology.
Marine Department: *Bulletin, Report.*
Massey Agricultural College: *Calendar, Bulletins.*
Polynesian Society: *Journal.*
State Forest Service: *Reports, Bulletins, Circulars, Leaflets.*
University of Otago: *Calendar, Proceedings Otago Medical School. Year Book.*

Pacific.

Pacific Science Congress: *Proceedings, Reprints.*

Australia

Australasian Antarctic Expedition: *Reports.*
Australasian Association for the Advancement of Science: *Reports.*
Australasian Institute of Mining and Metallurgy: *Proceedings.*
Australian Forestry Journal.
Australian National Research Council: *Science Abstracts.*
Department of Health: *Service Publication.*
Institution of Engineers: *Journal, Transactions, Selected Papers.*
Scientific and Industrial Research: *Journal, Circular, Reports, Pamphlets, Science and Industry.*

New South Wales.

Australian Museum: *Records, Annual Reports, Memoirs.*
Critical Revision of the Genus Eucalyptus.
Department of Agriculture: *Agricultural Gazette, Reports, Science Bulletin.*
Department of Fisheries: *Annual Report.*
Department of Mines: *Annual Report, Records, Mineral Resources.*
Linnean Society: *Proceedings.*
Parliamentary Publications.
Public Health Publications: *Report.*
Royal Society of New South Wales: *Journal and Proceedings.*
Royal Zoological Society: *Australian Zoologist.*
Sydney University: *Reprints.*

Queensland.

Geological Survey of Queensland: *Publication.*
Queensland Government: *Mining Journal.*
Queensland Museum: *Memoirs.*
Royal Geographical Society of Australia: *Journal.*
Royal Society of Queensland: *Proceedings.*

South Australia.

Adelaide Chamber of Commerce: *Annual Report.*
Mines Department: *Bulletin, Annual Report, Review of Mining Operations.*
Public Library, Museum, and Art Gallery: *Annual Report, Records.*
Royal Society of South Australia: *Transactions, Memoirs.*
University of Adelaide: *Publications.*

Tasmania.

Department of Mines: *Bulletin, Mineral Resources.*
Royal Society of Tasmania: *Papers and Proceedings.*

Victoria.

Field Naturalists' Club: *Victorian Naturalist.*
Mines Department and Geological Survey: *Annual Report, Bulletin, Records.*
National Herbarium of Victoria: *Australian Birds and Blossoms.*
National Museum: *Memoirs.*
Public Library, Museum, and Art Gallery: *Annual Report, Guides.*
Royal Society of Victoria: *Proceedings.*
University of Melbourne: *Collected Papers.*

Western Australia.

Geological Survey: *Annual Report, Bulletins.*
Royal Society of Western Australia: *Journal and Proceedings.*

United Kingdom.

Botanical Society of Edinburgh: *Transactions and Proceedings.*
British Antarctic Expedition: *Reports.*
British Association for the Advancement of Science: *Reports.*
British Astronomical Association: *Journal, Memoirs, List of Members.*
British Ecological Society: *Journal.*
British Museum: *Publications.*
Cambridge Philosophical Society: *Proceedings, Biological Sciences.*
Cambridge University, School of Agriculture: *Memoirs.*
Department of Scientific and Industrial Research: *Publications.*
Discovery.
Dove Marine Laboratory: *Annual Report.*
Edinburgh Geological Society: *Transactions.*
Empire Marketing Board: *Report.*
Geological Department, Glasgow University: *Papers, Monographs.*
Geological Survey of Great Britain and Ireland: *Memoirs, Summary of Progress.*
Geologists' Association: *Proceedings.*
H.M. Stationery Office: *Circular* (Monthly).

Imperial Bureau of Genetics: *Quarterly Bulletin.*
Imperial Institute: *Bulletin, Monographs.*
Imperial Institute of Entomology: *Review of Applied Entomology.*
International Society of Medical Hydrology: *Archives.*
Leeds Philosophical and Literary Society: *Annual Report, Proceedings.*
Leeds Geological Association: *Transactions.*
Linnean Society: *Journal, Proceedings, List of Members.*
Literary and Philosophical Society of Liverpool: *Proceedings.*
Liverpool Biological Society: *Proceedings.*
Manchester Literary and Philosophical Society: *Memoirs and Proceedings.*
Marine Biological Association: *Journal.*
Marlborough College Natural History Society: *Report.*
Natural History Society of Glasgow: *Glasgow Naturalist.*
North of England Institute of Mining and Mechanical Engineers: *Transactions.*
Norfolk and Norwich Naturalists' Society: *Transactions.*
Official Handbooks.
Rothamsted Experiment Station: *Report.*
Rowett Research Institute: *Reprints.*
Royal Anthropological Institute of Great Britain and Ireland: *Journal.*
Royal Botanic Gardens: *Notes.*
Royal Dublin Society: *Scientific and Economic Proceedings.*
Royal Empire Society: *United Empire.*
Royal Geographical Society: *Geographical Journal.*
Royal Irish Academy: *Proceedings.*
Royal Philosophical Society of Glasgow: *Proceedings.*
Royal Physical Society of Edinburgh: *Proceedings.*
Royal Scottish Geographical Society: *Magazine.*
Royal Society of Edinburgh: *Transactions, Proceedings.*
Royal Society of London: *Transactions, Proceedings, Year Book.*
Royal Satistical Society: *Journal.*
Scottish National Antarctic Expedition: *Scientific Results.*
Society for Preservation of the Fauna and Flora: *Journal.*
University of Birmingham: *Calendar.*
University of Durham Philosophical Society: *Proceedings.*
University of Oxford: *Calendar.*
Victoria Institute: *Journal.*
Zoological Society of London: *Proceedings, Transactions, List of Fellows.*
Victoria and Albert Museum: *Review of the Principal Acquisitions.*

AUSTRIA.

Akademie der Wissenschaften in Wien: *Sitzungsberichte, Mitteilungen.*
Geologische Bundesanstalt: *Abhandlungen, Jahrbuch.*
Geologische Reichsanstalt: *Verhandlungen, Jahrbuch.*
Naturhistorische Hofmuseums: *Annalen.*
Zoologisch-Botanisch Gesellschaft, Wien: *Verhandlungen.*

HUNGARY.

Botanisches Institute Museum, Szeged: ***Folio Cryptogamica.***
Hungarian National Museum: ***Annals.***
Magyar Tudomanyos Akademia, Budapest: ***Ertesito, Berichte.***
Universitatis Budapestinensis: ***Index Horti Botanici.***

BELGIUM.

Académie Royale de Belgique: ***Bulletin de la Classe des Sciences.***
Jardin Botanique de l'etat, Belgique: ***Bulletin.***
Musée Royal D'Histoire Naturelle de Belgique: ***Memoires, Annales, Resultats Scientifiques du Voyages aux Indies Orientales Ne'erlandaises.***
Société Geologique de Belgique, Liége: ***Annales, Bulletin.***
Société Royale de Botanique de Belgique: ***Bulletin.***
Société Royale Zoologique de Belgique: ***Annales.***
Société Scientifique de Brussels: ***Annales.***

CZECHOSLOVAKIA.

Charles University, Prague: ***Studies from the Plant Physiological Laboratory.***
Deutchen Naturwissenschaftlich-medizinischer Verein fur Bohem, Prague: ***Lotos.***
National Museum (Entomological), Prague: ***Sbornik.***
Societe Royale des Sciences de Boheme, Prague: ***Memoires, Compte-Rendu.***

DENMARK.

Academie Royale des Sciences et des Lettres de Danemark: ***Skrifter, Forhandlinger Meddelelser.***
Danmarks Geologiske Undersogelse, Copenhagen: ***Publications.***
Dansk Geologisk Forening, Kobenhaven: ***Meddelelser.***
Dansk Naturhistorisk Forening i. Kobenhaven: ***Viden. Meddelelser.***
Zoological Museum, Copenhagen: ***Danish-Ingolf Expedition.***

FINLAND.

Academia Aboensis, Abo: ***Humaniora.***
Geologique Commissionen de Finland: ***Bulletin.***
Societas pro Fauna et Flora Fennica: ***Memoranda: Acta, Meddelan.***
Societe de Geographie de Finland: ***Fennica, Acta.***
Societas Scientarium Fennicae: ***Acta, Ofversigt; Bidrag, Arsbok, Commentations.***

FRANCE.

Chimie et Industrie, Paris.
Janet, Charles: ***Publications.***
Musée d'Histoire Naturelle, Paris: ***Bulletin, Nouvelle Archives.***
Société Astronomique de France: ***Bulletin.***
Société de Geographie: ***Bulletin.***
Société Linnéene de Bordeaux: ***Actes.***
Société Linnéene de Normandie, Caen: ***Bulletin.***
Société des Sciences Physiques et Naturelles, Bordeaux: ***Memoires, Proces-Verbeaux.***
Société Zoologique de France: ***Bulletin.***
University of Grenoble: ***Annals.***

GERMANY.

Akademie der Wissenschaften, Leipzig: *Berichte, Abhandlungen.*
Bayerische Akademie der Wissenschaften, Munich: *Sitzungsberichte.*
Berlin Mathematischen Gesellschaft, Gottingen: *Sitzungsberichte.*
Botanische Verein der Provinz Brandenburg: *Verhandlungen.*
Bremer Wissenschaften Gesellschaft: *Schriften, Abhandlungen.*
Deutschen Akademie der Halle: *Leopoldina.*
Deutsche Entomolog Museum: *Mitteilungen, Arbeiten.*
Gesellschaft der Wissenschaften zu Gottingen: *Nachrichten, Mitteilungen.*
Naturwissenschaftlichen Verein, Bremen: *Abhandlungen, Festschrift.*
Hamburg University: *Publications.*
Institut Grand-Ducal de Luxembourg: *Archives.*
Museum fur Volkerkunde, Dresden: *Abhandlungen, and Berichte.*
Naturforschenden Gesellschaft, Freiburg: *Berichte.*
Naturhistorisch-Medizinschen Verein, Heidelburg: *Verhandlungen.*
Naturhistorischen Gesellschaft, Hanover: *Jahresberichte, Beihefte.*
Naturhistorisches Museum in Hamburg: *Mitteilungen.*
Naturhistorische Verein der Preussischen Rheinlande und Westfalens, Bonn: *Verhandlungen, Sitzungsberichte.*
Naturwissenschaften Verein in Hamburg: *Verhandlungen, Adhandlungen.*
Naturwissenschaftliche Verein fur Schleswig-Holstein: *Schriften.*
Oberheinischer Geologischen Verein, Tubingen: *Jahrbuch und Mitteilungen.*
Physikalisch-Okonomische Gesellschaft, Konigsberg: *Schriften.*
Preussischen Akademie der Wissenschaften, Berlin. *Sitzungsberichte.*
Preussische Geologischen Landesanstalt, Berlin: *Jahrbuch.*
Senkenbergische Naturforschende Gesellschaft, Frankfurt-am-Main: *Natur und Museum, Berichte, Senckenbergiana*
Staatlichen Sammlungen fur Kunft, Dresden: *Berichte.*
Verein fur Vaterlandischen Naturkunde in Wurtenburg, Stuttgart: *Jahreshefte Mitteilungen.*
Zool. u. Anthropol-Ethnol Museum, Dresden: *Abhandlungen.*
Zoologischen Museum, Berlin: *Mitteilungen, Berichte.*
Zoologischen Staatsinstitut und Museum, Hamburg: *Mitteilungen.*

HOLLAND AND DUTCH EAST INDIES.

Kong. Akademie Van Wetenschappen, Amsterdam: *Proceedings, Verhandelingen.*
Leidsche Geologische, Leiden: *Mededelingen.*
Musée Teyler, Haarlem: *Archives.*
Nederlandsch Aardrijksundig Genootschap, Leiden: *Tijdschrift, Register.*
Nederlandsch Aardrijkskundig Genootschap, Amsterdam: *Tijdschrift.*
Nederlandsche Entomologische Vereeniging, Amsterdam: *Tijdschrift, Berichten Verslagen.*
Rijks Ethnographisch Museum, Leiden: *Katalog, Verslag.*
Societe Hollandaise des Sciences: *Archives Neerlandaises, Sciences Exactes.*
Teyler's Godgeleerd Genootschap: *Verhandlingen.*

Banka Tin: *Jaarverslag* von de Winning.
Bataviaasch Genootschap van Kunsten en Wetenschappen, Batavia: *Tijdschrift, Verhandelingen.*
Kon. Natuurkundige Vereeniging in Nederlandisch-Indie: *Natur-kundig Tijdschrift.*
Mijnwesen in Nederlandsche Oost-Indie, Batavia: *Jaarboek*

ITALY.

Accademia Scientifica Veneto-Trentino Istriana, Padova: *Atti*
Cometato Nazionale Italiano: *Bolletino.*
Giornale Botanico Italiano.
Laboratorio di Entomologia di Bologna: *Bolletino.*
Laboratorio di Zoologia generale e agraria, Portici: *Bolletino*
Musei Civico Storia Naturale, Genova: *Annali.*
Musei di Zoologia ed Anatomia comparata R. Università di Torino: *Bolletino.*
Reale Accademia dei Lincei, Roma: *Rendiconti, Atti.*
R. Società Geografica Italiana: *Bolletino*
R. Ufficio Geologico d'Italia: *Bolletino.*
Società Africana d'Italia, Naples: *Bolletino.*
Società Botanico Italiana, Firenze: *Bolletino.*
Società Toscana di Scienze Naturali, Pisa: *Memoirs, Processi verbali.*
Zoologia e Anatomia Comparata Musei Universita Genova: *Bolletino.*

NORWAY.

Bergens Museum: *Arbok.*
Norwegian Meteorologischen Institut, Oslo: *Jahrbuch.*
Norwegian North Polar Expedition.
Nyt Magazin for Naturvidenskaberne.
Tromso Museum: *Arshefter, Skrifter, Arsberetning.*

POLAND.

Societe Botanique de Pologne: *Acta Societatis, Compte Rendu.*
Societe Polonaise des Naturalisses, Lwow: *Kosmos.*
Universitatis Voronegiensis: *Acta.*
Zoologici Musei Polonici Historiae Naturalis, Warsaw: *Annales, Prace Zoologiczne, Fragmenta Faunista, Acta.*
University of Tartu, Dorpat (Esthonia): *Acta Commentationes.*

U.S.S.R.

Academie des Sciences: Publications.
Arctic Institute of the U.S.S.R.: *Bulletin, Transactions.*
Institute for Scientific Exploration of the North: *Transactions.*
Biological Station, Saratov: *Arbeiten, Hydrobiologische Zeitschrift.*
Latvyas Universitates Botaniska Darza Rakste, Riga: *Acta.*
Musee Geologique Pierre le Grand, Leningrad: *Travaux.*
Problems of Soviet Geology.
Societe Imperiale des Naturalistes, Moscow: *Bulletin.*
Societe Entomologique de Russie, Leningrad: *Revue Russie d'Entomologie.*

Spain.

Junta de Ciencias Naturales de Barcelona: Publications.
Reale Academia de Ciencias, exactes, fisicas, y naturales de Madrid: *Memoirs, Revista.*
Instituto Botanico da Universidade de Coimbra (Portugal): *Boletin, Memorias.*

Sweden.

Botaniska Notiser, Lund.
Botaniska Tradgard, Goteborg: *Acta Horti.*
Geological Institution of the University of **Uppsala**: *Bulletin.*
Geologiska Foreningens, Stockholm: *Forhandlinger.*
Kungl. Fysiografiska Sallskapets, Lund: *Forhandlingar.*
Statens Meteor.-Hydrografiska Anstalt: Publications.
Observatoire Meteorologique de L'Universite, **Uppsala**: *Bulletin Mensuel.*
Kungl. Svenska Vetenskapsakad: *Arkiv, Handlingar, Arsbok, Les Prix Nobel.*
Sveriges Offentliga Bibliothek, Stockholm: *Accessions Katalog.*
Societe Entomologique a Stockholm: *Tidskrift.*
Svenska Mosskultur Foreningens, Jonkoping: *Tidskrift.*
Svenska Naturskydds Foreningens, Stockholm: *Sveriges Natur.*
Svenska Sallskapet for Anthropologi och Geografi, Stockholm: *Annaler.*
Sveriges Geologiska Undersokning: Arsbok.
University of Lund: *Arsskrift, Acta.*
Zoologiska Bidrag, Uppsala.

Switzerland.

Naturforschende Gesellschaft, Basel: *Verhandlungen.*
Naturforschende Gesellschaft, Bern: *Mittheilungen, Verhandlungen, Actes.*
Naturforschende Gesellschaft, Zurich: *Vierteljahrsschrift.*
Societe Vaudois des Sciences Naturelle, Lausanne: *Memoirs, Bulletin.*
Schweizerschen Naturforschenden Gesellschaft, Aarau: *Verhandlungen, Actes.*
Societe de Physique et D'Histoire Naturelle, Geneve: *Compte Rendu, Memoires.*

India.

Academy of Sciences, Allahabad: *Bulletin.*
Agricultural Department, Calcutta: *Reports.*
Anthropological Society, Bombay: *Journal.*
Asiatic Society of Bengal: *Journal and Proceedings.*
Botanical Survey of India: *Records.*
Geological Survey of India: *Records, Memoirs, Palaeontologia Indica.*
Imperial Department of Agriculture, Pusa: *Report.*

Ceylon.

Ceylon Journal of Science.
Colombo Museum: *Spolia Zeylanica.*

China.

Fan Memorial Institute of Biology: *Bulletin, Report.*
National Library of Peking: *Report.*
National Research Institute of Biology: *Sinensia.*
Shanghai Science Institute: *Bulletin, Journal.*
Science Society of China, Shanghai: *Transactions, Contributions (Zoology).*

Turkestan.

Scientific Society of Turkestan:: *Transactions.*
University of Central Asia: *Acta. Bulletin.*

Egypt.

Ministry of Finance: *Geological Publications.*

Japan.

Hiroshima University: *Journal of Science.*
Imperial Academy, Tokyo: *Proceedings.*
Imperial Earthquake Investigation Committee, Tokyo: *Publications.*
Imperial Geological Survey of Japan: Report, *Miscellaneous publications.*
Imperial University of Tokyo: *Journal of the Faculty of Science.*
Kyoto Imperial University: *Memoirs.*
National Research Council· *Report, Journals, Records of Oceanographic Works.*
Ohara Institute, Okayama: *Berichte.*
Taihoku Imperial University: *Memoirs, Transactions.*
Tohoku Imperial University, Sendai: *Science Report.*
Tokyo Bunrika Daigaku: *Science Reports.*
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